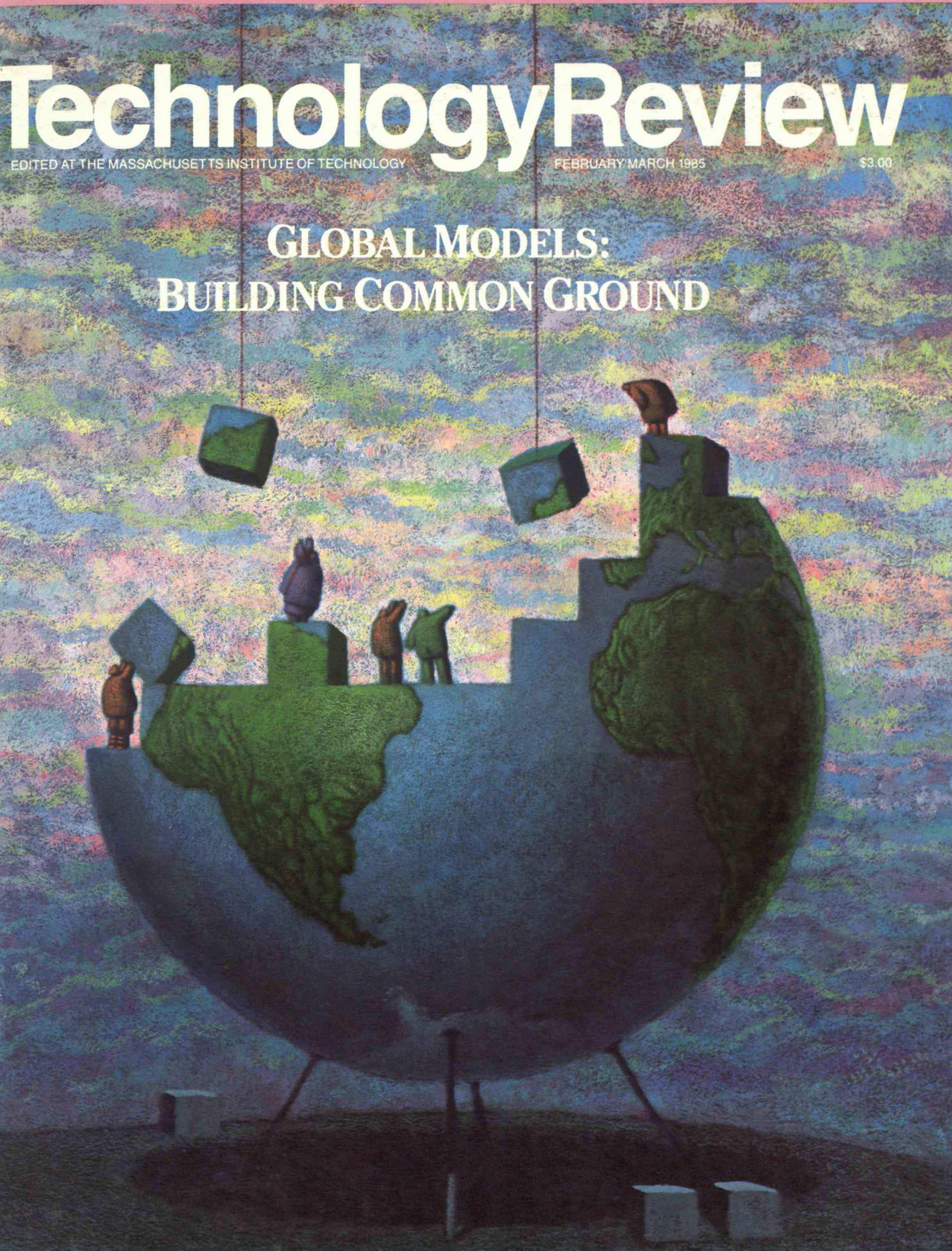
▪ ARTIFICIAL PROCREATION ▪ THE REAGAN SCIENCE POLICY ▪

Technology Review

EDITED AT THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY FEBRUARY/MARCH 1985 $3.00

GLOBAL MODELS: BUILDING COMMON GROUND



The Mercedes-Benz 300D Sedan, 300TD Station Wagon and 300CD Coupe: with their Turbodiesel performance, they are

The Mercedes-Benz Turbodiesels for 1985: still the most powerful line of diesels sold in America.

THE MERCEDES-BENZ 300D Sedan, 300TD Station Wagon and 300CD Coupe represent three variations on a radical theme: the idea that dramatic over-the-road performance can be blended with diesel efficiency and stamina.

The idea works. These Mercedes-Benz Turbodiesels *move*. With accelerative energy and cruising ease worthy of gasoline-powered cars. With power enough to flatten hills and make quick work of sudden passing maneuvers.

TURBODIESEL POWER, DIESEL DURABILITY

Yet consider the bottom line. The Turbodiesel you will be living with and maintaining and paying the bills for, year in and year out, is a true-blue diesel. No complex electrical system. No conventional tune-ups. A durability factor that has become part of automotive folklore.

The key to the Mercedes-Benz Turbodiesels' performance is less the *turbo* than the *diesel*–its three-liter, five-cylinder engine.

It is unique, a high torque powerhouse so advanced that it even oil-cools its own pistons as they move.

Turbocharging any engine boosts its power. Turbocharging this engine boosts its power–by 42 percent in models sold on the West Coast, by 45 percent in models sold elsewhere.

Many makers have aped the Turbodiesel idea since Mercedes-Benz pioneered it in production automobiles in 1978. Scant surprise that no maker has yet aped the Mercedes-Benz Turbodiesels' vivid level of performance.

The Turbodiesels rank not only as the most powerful but also the most *varied* line of diesels sold in North America today.

SEDAN, STATION WAGON AND COUPE

The four-door 300D Sedan accommodates five persons and a gaping 12-cu.-ft. trunk within a wheelbase of just 110 inches, helping lend near sports-sedan agility to this familiy-sized automobile.

"The 300D's success in striking a balance between ride comfort and handling response," reports one automotive journal, "is equalled by less than a handful of other cars in the world."

The 300TD Station Wagon interlaces the driving pleasures of a Mercedes-Benz with the workhorse utility of a five-door carryall. Total cargo capacity well exceeds 100 cu. ft. A hydropneumatic *leveling* system is integrated with the rear suspension, to help keep the vehicle riding on an even keel–whether the load is heavy or light.

EXOTIC, YET PRACTICAL

The 300CD Coupe is the world's only limited-production two-plus-two diesel touring machine. It sits on a taut 106.7-inch wheelbase–one secret of its quick-witted

diesels apart. With their handling agility and riding comfort and obsessively fine workmanship, they are automobiles apart.

agility. Its graceful coupe bodywork, sans central door pillars, is formed in a process involving intensive handworkmanship. The 300CD is that rarity of rarities, an automobile both highly exotic *and* relentlessly practical.

Sedan or Station Wagon or Coupe, Mercedes-Benz Turbodiesel power is harmonized with high standards of performance in every sense of the word.

From suspension to steering to brakes, every Turbodiesel is engineered to be a precision driving instrument. "There's a cornucopia of driving delights at your disposal," concludes *Car and Driver*–suggesting that in driving precision there is driving pleasure.

From biomechanically correct seats, to a superb automatic climate control system, to the dulling of the outside wind noise to an almost inaudible murmur, remarkable comfort prevails. Virtually every *useful* driving amenity is standard, including an uncannily precise electronic cruise-control unit.

Safety precautions are remarkably comprehensive–both in helping avoid trouble, and in protecting the occupants should trouble occur.

MORE THAN POWER

Ultimately, the Turbodiesels' appeal extends beyond their performance and driving pleasure. There is no more powerful line of diesels sold in North America–and there may be no more versatile, more competent, more timely line of automobiles. In North America, or the world.

Engineered like no other car in the world

SEE YOUR AUTHORIZED MERCEDES-BENZ DEALER

FEB/MAR 1985 VOL. 88 NO. 2 EDITED AT THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY

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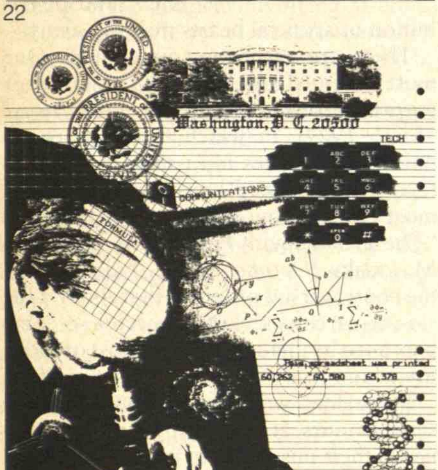

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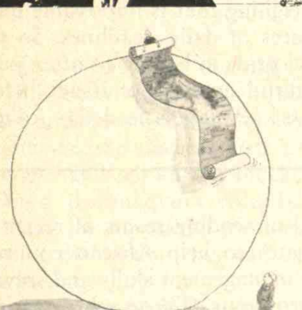

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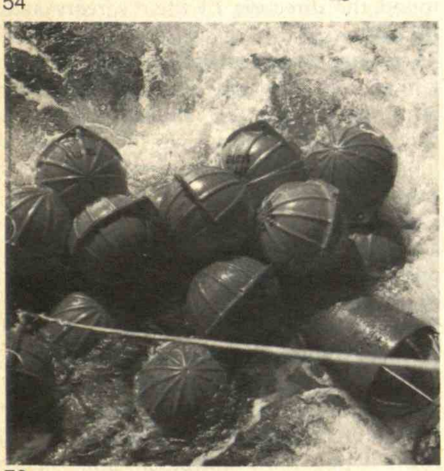

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TechnologyReview

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Technology Review (ISSN 0040-1692), Reg. U.S. Patent Office, is published eight times each year (January, February/March, April, May/June, July, August/September, October and November/December) at the Massachusetts Institute of Technology. Two special editions are provided for graduate (pp. A1-A24) and undergraduate (pp. A1-A24 and B1-B16) alumni of M.I.T. Entire contents © 1985 by the Alumni Association of M.I.T. Printed by Lane Press, Burlington, Vt. Second-class postage paid at Boston, Mass. and additional mailing offices. Postmaster: send address change to M.I.T., Room 10-140, Cambridge, Mass. 02139.

Editorial, circulation, and advertising offices: *Technology Review*, Room 10-140, Mass. Institute of Technology, Cambridge, Mass. 02139 (617) 253-8250.

Advertising representatives:
The Leadership Network: 254 Fifth Ave., New York, N.Y. 10001 (212) 684-5500; Benson Co., Park Ridge, Ill.; Colin Smith Agency, Berkeley, Calif.; Joe DeLone & Associates, Wayne, Pa., Fairfield, Conn., Lincoln, Mass.; J. J. Arcisz Co., Boston, Mass.; and McKeldin Co., Atlanta, Ga.
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Subscription inquiries and change of address: Room 10-140, M.I.T., Cambridge, Mass. 02139 (617) 253-8292.

Prices:
Subscriptions, one year: libraries and organizations $27; all others $24. Canada add $6; other foreign countries add $12. Single copies and back issues available. All prices U.S. funds.
U.S.A. newsstand distribution by Eastern News Distributors, Inc., 111 Eighth Ave., New York, N.Y. 10011.

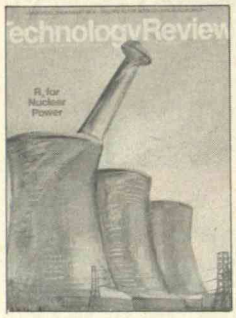
You See It Here First

Outpacing the News

Six months ago Nevin S. Scrimshaw wrote in these pages that the food aid policies of the Western nations have not helped, and may actually have compromised, the ability of many Third World nations to feed their hungry. He also predicted that without dramatic changes problems of hunger and malnutrition would worsen (*August/September 1984*). Scrimshaw's article forecast the tragedy in northeastern Africa more sharply than we imagined.

"The Politics of Starvation" is but one recent example of *Technology Review*'s service in previewing for our readers problems arising at the interface of technology and society. In "The Not-So-Clean Business of Making Chips" (*May/June*), Joseph LaDou first called to public attention potential health hazards in the semiconductor industry that are now becoming a major issue for high technology.

Perhaps our most stunning recent preview, however, came in the contributions from Barton J. Bernstein and Harvey V. Fineberg in the November/December issue. Both these authors raised troubling questions about the technical feasibility, ethics, and politics of the artificial heart. Only two weeks after the articles appeared, William J. Schroeder received an artificial heart, amidst intense publicity, at the privately owned Humana Heart Institute in Louisville. Bernstein had warned



that "business firms, less susceptible to effective control than medical schools, . . . may soon dominate the artificial-heart business. The possibility of meaningful control over development and distribution of artificial hearts may slip away."

There are earlier examples, too. Our most reprinted articles are the set on "Prescriptions for Nuclear Power" (*February/March 1984*), in which five authors reported alternatives for a safer nuclear future. This followed by three months our most talked-about article in recent years, "The Trouble with Fusion," by Lawrence M. Lidsky (*October 1983*). Lidsky made the controversial proposal that today's fusion research is seeking a reactor so complex as to be unacceptable to most of those for whom it is planned.

Magazines with publication schedules such as ours are not supposed to make news; their mission is to provide the careful weighing that is impossible under the pressures of daily deadlines. So we take special pride in having so often published thoughtful analysis of issues before our readers knew it was needed.—*John Mattill*

Solving Tomorrow's Problems with Today's Technology

The cover story in this issue (*"Charting the Way the World Works," by Donella Meadows*) is the first of several articles commissioned by *Technology Review* with the help of former students and colleagues to honor the late Carroll L. Wilson, who was Mitsui Professor, Emeritus, in Problems of Contemporary Technology at M.I.T. when he died early in 1983.

Wilson took charge of a major interface of technology and policy in 1947, when he became first general manager of the U.S. Atomic Energy Commission. But his best-remembered contributions began 10 years later, when he joined the Sloan School of Management and began a series of projects on major global problems.

Sensing a "leadership vacuum" among the then-new nations of Africa, Wilson conceived of sending teams of recent M.I.T. graduates to help African countries develop management skills and solve pressing problems. Those who participated found the direction of their careers and the nature of their lives forever changed. Then came studies on using single-cell protein to relieve world hunger, mitigating effects on climate, the value of alternative energy sources, using world coal, and finally replacing nuclear arms with conventional ones.

The common denominator in all these activities was Wilson's sense that *future* problems, however dimly perceived, might be averted by intelligent application of *present* technology. Perhaps the editors' highest aspiration for this magazine is that its readers might share at least some of that perceptive vision of the potential of today's technology to improve tomorrow's lives.—*John Mattill*

Chip Making, Singapore Software, Hydrogen Fuel

The Dangers of Making Chips

Your articles on the effects on human health of the semiconductor industry imply that there is a permissible degree of sloppiness, subject to litigation and quibbling, in running a dangerous operation. *(See "The Not-So-Clean Business of Making Chips" by Joseph LaDou, May/June, page 22.)* I suggest a revolutionary approach: do things the way we did in the emerging aircraft industry. With headlines blazing every accident involving aircraft, safety became the moral and economic key to survival. Every known or suspected risk was reduced almost to zero. The result has been an excellent and ever-improving safety record, for both customers and workers, over the past 50 years.

Not until later did the idea that airlines were playing dice with passengers' lives rear its ugly head. The concept of "acceptable contamination levels" in industry seems to be tarred with the same brush. Considering the hidden costs of litigation, safety experts, bureaucratic wrangling, public relations, etcetera, I suggest that legislation be devised to reward the manufacturers who put down their guns first.

J.R. Foley
Vernon, Conn.

Nuclear fission has been the main economical solution to the world's increasing energy demands for some decades. Despite these demands, the development of nuclear energy has been all but blocked by uninformed doomsayers like Joseph LaDou, who are supported by whatever publicity for their views they can extract from the media.

Our current major high-tech product comes from Silicon Valley. Are you bent on helping LaDou destroy that product? When a political battle like this one is in the making, *Technology Review* should either stay out or come out *in favor* of technology.

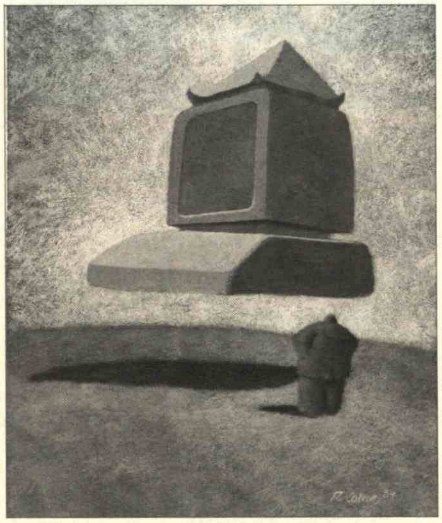
John Granlund
Charlottesville, Va.

Alison Bass's article about definitions of injury and illness in the microelectronics industry (*May/June, page 33*) was especially interesting. It calls to mind the fact that in some recent court cases, medical experts have had to educate judges regarding the uses of the word "injury" in science and medicine.

Record keeping for industrial accidents can be complicated. Coal miners severely injured in mine accidents used to be given office or even groundskeeping jobs so their injuries would not have to be reported. Another problem is that information on environmental and occupational illness usually includes only a patient's last occupation, when a disease might actually be traced to a previous occupation.

Jerrold L. Abraham
Syracuse, N.Y.

Dr. Abraham is associate professor and director of environmental and occupational pathology at the State University of New York.



Software from Singapore

In "Will High Technology Come from Southeast Asia?" (*November/December, page 10*), Marshall Goldman makes several errors in fact and, more importantly, of interpretation.

The population of Singapore is 2.5 million, not 5 million, as Goldman reports. Nor is the National University of Singapore the only university. Though more specialized, Singapore Polytechnic, Ngee Ann Polytechnic, and Nanyang Technological Institute are of similar academic level. Hence, 15 to 20 percent of the population, rather than 9 percent, has access to university-level education.

Nor has Singapore adopted a strategy of foregoing innovation, as Goldman suggests. The explicit policy of Prime Minister Lee Kuan Yew is to seize leadership in high-tech industries—from computer software to robotics to alternative energy—in Southeast Asia. The specific objective of Singapore's National Computer Board (NCB) is to make Singapore a center for world software development by 1990. The government has made an extraordinary effort to develop skilled labor in this field, of which the four university-level institutions are only a part.

For example, the University of Singapore, with the help of IBM, established the Institute of Systems Science in 1981. Sony and the Japanese government have collaborated with the NCB to create the Japan-Singapore Institute of Software Technology. And International Computers Limited (of the United Kingdom) and Ngee Ann Polytechnic joined to establish the Center for Computer Studies. These produce between 600 and 700 computer professionals each year, the target being 8,000 by 1990. Before 1980, Singapore had a total of 800 computer specialists.

Although Singapore is not devoting resources to inventing new generations of computer hardware, the country has expended considerable effort to induce foreign firms to set up R&D facilities on the island. All these efforts have generated astonishing economic growth. Singapore's per capita national product is now about $5000 per year, second in Asia only to Japan. The objective is to achieve $10,000 by 1990, roughly where Japan is now.

Richard D. Robinson
Cambridge, Mass.

The writer is professor of international management at M.I.T.'s Sloan School.

The author responds:
I did err in stating that the population of Singapore is 5 million. However, in both my own visit to Singapore and checks with the Singapore Embassy in Washington, I found that there is indeed only one university, the National University of Singapore. The other institutes are not universities in the commonly accepted meaning of the word, nor are they institutes like M.I.T. They do not provide significant graduate or more advanced work, and few of their students even do undergraduate-level work.

Singapore is schooling specialists in the use of computers and software, but they will largely receive "hands-on," advanced vocational training. This is hardly university-level work like that being done in Ja-

Continued on page 20

Shackling Lunar Developers

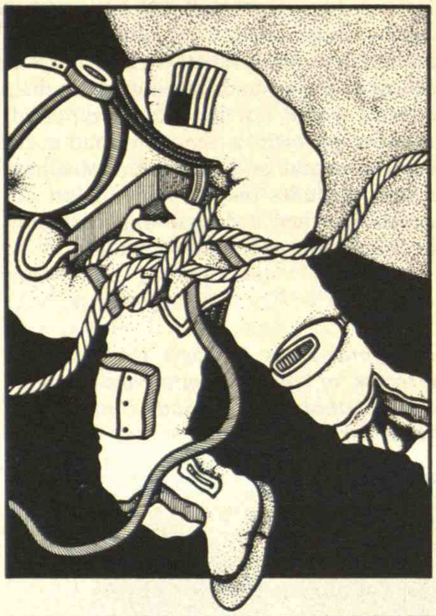
NEARLY 16 years after men first walked the cratered surface of the moon, NASA and its advisors sense the time is ripe to think about returning there. They are probably right. Establishing lunar missions would be relatively easy after developing the space station and the orbit-to-orbit ferry craft, which the National Aeronautics and Space Administration (NASA) hopes to have in place in the 1990s. Indeed, if such a system is the next logical step in space, as NASA contends, then a moon base may well be the next logical step beyond that. But to ensure the viability of such a base, NASA will have to work its way—soon—through a thicket of international law. The crucial issue to be answered: who owns the right to what in space?

Even the space agency's erstwhile critics at the congressional Office of Technology Assessment (OTA) are urging the moon planners on. An OTA study released in November criticized NASA's specific space-station proposal as trying to do too much too soon, reflecting the view of several other critics (*see "The Manned Space Station: NASA's Last Hurrah?" page 12*). The OTA warned against making a major commitment to orbiting hardware before clearly formulating long-range goals to guide the investment. Among these suggested aims were broad exploration of the solar system and lunar settlement.

The U.S. space community needs little prodding to think big. The practicality—and even inevitability—of some kind of lunar occupation was taken for granted at a NASA-sponsored symposium on Lunar Bases and Space Activities in the 21st Century, held in October. "We now know we can get there," NASA Administrator James M. Beggs observed. "The question is, what should we be doing?"

A Lunar Base Working Group has already given NASA a preliminary answer. The group concluded that "among the possible alternative goals that can follow the space station, a permanent base on the moon offers the most robust combination of factors that will foster steady long-term growth for our nation's space future."

ROBERT C. COWEN IS SCIENCE EDITOR OF THE CHRISTIAN SCIENCE MONITOR *AND FORMER PRESIDENT OF THE NATIONAL ASSOCIATION OF SCIENCE WRITERS.*



International law may throw a wrench into plans to build a moon base.

Those benefits, the study notes, include the possibility of mining oxygen, which is abundant in the rocks on the lunar surface, and using moon materials for constructing facilities in space. Supplying rocket fuel made with lunar oxygen to Earth-orbiting spacecraft might be cheaper than lifting the fuel from Earth against our planet's much stronger gravity, for example. Material from the moon or asteroids might also provide a relatively cheap and easy way of hardening military spacecraft, making a Star Wars missile-defense system more feasible, according to Arthur Kantrowitz of Dartmouth College.

The working group noted the importance of the moon as a base for large-scale astronomical observations and other research programs. Finally, the group cited an important intangible factor in the "grand aspirations that will establish the first human society on another planet"—they will mark a "cultural watershed of sufficient magnitude to inspire broad public support and international respect."

This hype contains the echo of an important immediate problem. Moon bases and mining may be twenty-first-century projects, but the international laws that will govern them are being worked out now. NASA plans are cast in terms of the U.S. national interest, with only an occasional tip of the hat to international cooperation. But NASA, U.S. companies, and private citizens are bound by the international treaties that the United States signs and ratifies. And although U.S. space enthusiasts may talk grandly of establishing "the first human society on another planet," the rest of the world seems determined to put its own stamp on it.

Sovereignty in Space

The fundamental differences in viewpoint that have made the Law of the Sea Treaty controversial have already opened a potentially damaging rift among nations over space development. This conflict stems from the difference—a major one—between considering the solar system beyond Earth as the "province of all humankind" and seeing it as the "common heritage of humankind."

The former is the old concept of freedom of the seas extended to the solar system. No nation can claim sovereignty, yet all have equal rights and equal access. Thus, only those nations that invest in space reap the rewards from their investment. This concept is embodied in the Treaty of Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies. Ratified by 85 countries, one of which is the United States, this "outer space treaty" currently provides the basic space-law framework. Subsidiary treaties governing astronaut rescue, liability, and regulation of satellites and other human-made space objects reflect its provisions.

"Common heritage"—a concept that Steven Gorove, a legal scholar at the University of Mississippi, told the symposium is "not well defined"—proclaims that all nations could claim a share of the profits of space development, regardless of who contributes to the investment. This equal-ownership principle is embodied in the Law of the Sea Treaty and in the Agreement Governing the Activities of States on the Moon and Other Celestial Bodies.

Continued on page 77

ILLUSTRATION: LUCY RASTETTER

Masterslice and the Engineering Design System

IBM

To: Abby
From: Roger
Subject: IBM Technology

I've been reviewing some of our past and present technological achievements, and it occurred to me that the scientific, engineering, and academic communities might like to know more about them. Will you select a topic from the following list?

Thanks.

Vacuum tube digital multiplier
IBM 603/604 calculators
Selective Sequence Electronic Calculator (SSEC)
Tape drive vacuum column
Naval Ordnance Research Calculator (NORC)
Input/output channel
IBM 608 transistor calculator
FORTRAN
RAMAC and disks
First automated transistor production
Chain and train printers
Input/Output Control System (IOCS)
STRETCH computer
"Selectric" typewriter
SABRE airline reservation system
Removable disk pack
Virtual machine concept
Hypertape
System/360 compatible family
Operating System/360
Solid Logic Technology
System/360 Model 67/Time-Sharing System
One-transistor memory cell
Cache memory
Relational data base
First all-monolithic main memory
Thin-film recording head
Floppy disk
Tape group code recording
Systems Network Architecture
Federal cryptographic standard
Laser/electrophotographic printer
First 64K-bit chip mass production
First E-beam direct-write chip production
Thermal Conduction Module
288K-bit memory chip
Robotic control language
Masterslice and the Engineering Design System

Roger-
Let's tell about our innovative method of designing and integrating logic chips into our large computers.
Abby

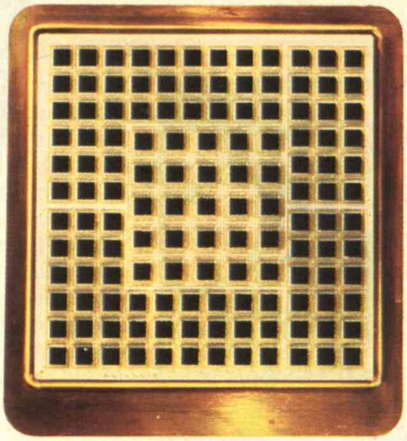
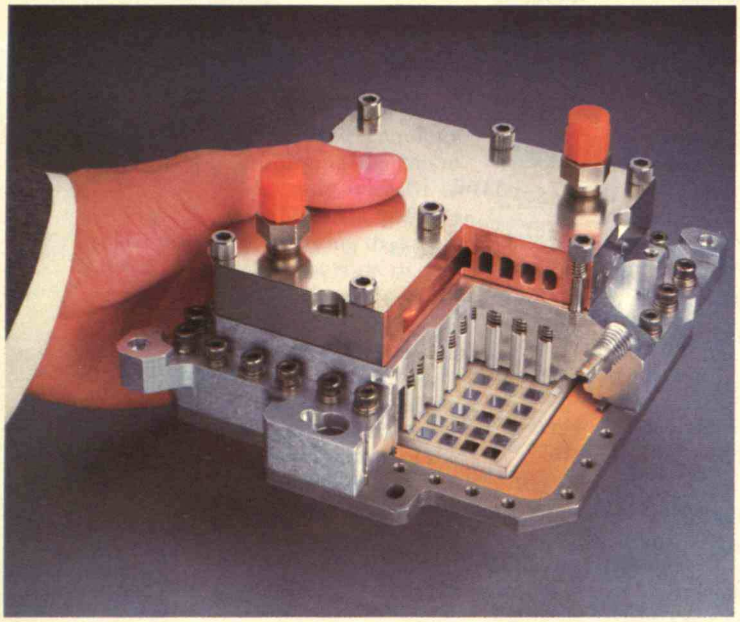


Figure 1: *The logic module used in large IBM computers (cutaway below) is part of the industry's densest circuit packaging. The electronic chips mounted in each module (right) were made through IBM's Engineering Design System and the masterslice concept: customize where necessary, standardize where possible.*



As computer applications continue to expand, designers of large computers are faced with many challenges. One of the biggest of these is designing semiconductor chips: not only do engineers have to design chips to contain the desired function, but they must also integrate the chips into the rest of the system and accomplish this quickly and inexpensively.

For nearly two decades, IBM designers have been leaders in this field, pioneering the technologies of chip customization, automated design, and automated manufacturing. In the mid-1960s, IBM researchers began developing a chip customization technology—known as gate array or masterslice—as well as a totally integrated set of design automation tools called the Engineering Design System.

The first masterslice chip came off IBM production lines in 1967 and was part of the System/3 announced in 1969. Growing increasingly important as an element in IBM computers, masterslice became the basis for the logic in the System/38 in 1978. This marked the first major impact of masterslice technology on computer architecture, making masterslice a driving force in semicustom, large-scale integration of chips in the computer industry.

In masterslice, a predefined pattern of circuit elements is fabricated in an area of a silicon chip called a cell. The pattern is then repeated so that almost the entire chip is covered with identical cells. In this manner, many chips

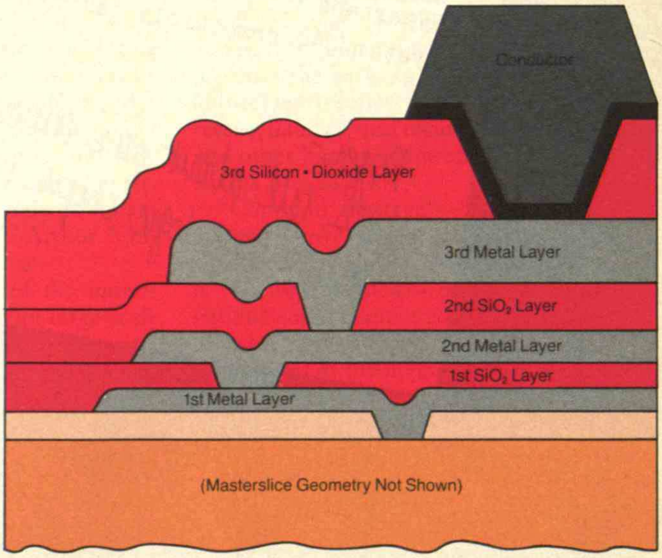


Figure 2: *This simplified side view of a logic chip shows three layers of metallization (along with three layers of insulating silicon dioxide) that are put on top of the masterslice to produce a semicustom chip. The metallization process enables designers to customize chips for a specific job. And a standard "base"—the masterslice—allows quicker turnaround times and lower manufacturing costs.*

Masterslice and the Engineering Design System

may be produced with identical arrays of identical cells.

Customization takes place in "metallization"—the adding of alternate layers of insulators and metal wiring interconnections over the masterslice pattern of the circuit elements. This gives chip designers the freedom to make hundreds of variations in their design and still maintain the economic standardization of parts.

Masterslice technology has grown into an important process for implementing logic in IBM products. It is the basis of the 1,200 logic chips that make up the 500 different logic configurations of the central processing unit of IBM's largest computers, the 308X family.

IBM's Engineering Design System (now a full family of integrated design tools) has a data base that contains a complete description of each chip and its relation to the rest of the system, from the physical properties of individual devices to the requirements of the entire logic system of the computer. Thus, this design system enables

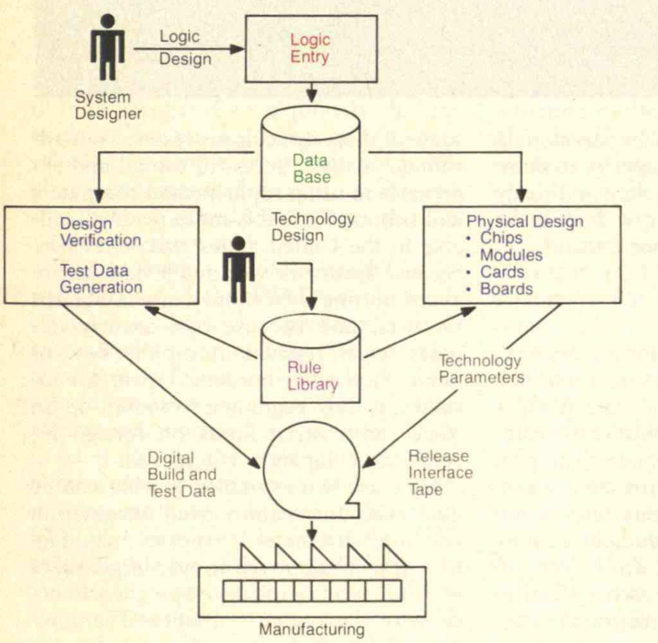


Figure 3: *With IBM's Engineering Design System, machine designers use terminals to input logic functions for a chip and establish a data base. Through simulation, the system provides logic verification and performs logic delay checking. Test patterns are then automatically generated for each part. In the meantime, physical design of the chip is done with computer programs that perform the following tasks: circuit placement, I/O assignment, wiring, and checking. All physical design information is then transformed into shapes, patterns, and precise locations of interconnections and circuit elements required for manufacturing.*

Figure 4: *Shown here is a display screen from the Interactive Graphic System (IGS), one of the many Engineering Design System tools developed by IBM to speed chip development and implementation. IGS is a powerful shape manipulation tool used to design new masterslices.*

the needs of a large system to be reflected in the design of its smallest components.

The thousands of individual software modules of the Engineering Design System can be used to take a chip from initial design, through simulation and testing, to manufacture. Linking such a wide range of functions through common interfaces to form a total system is a feat unmatched in the industry. A designer using this system can take a chip from the start of the physical design stage to the manufacturing line in about six days.

Many engineers, scientists, and programmers throughout IBM contributed to the development of masterslice and the Engineering Design System. Their contributions are only part of IBM's continuing commitment to research, development, and engineering.

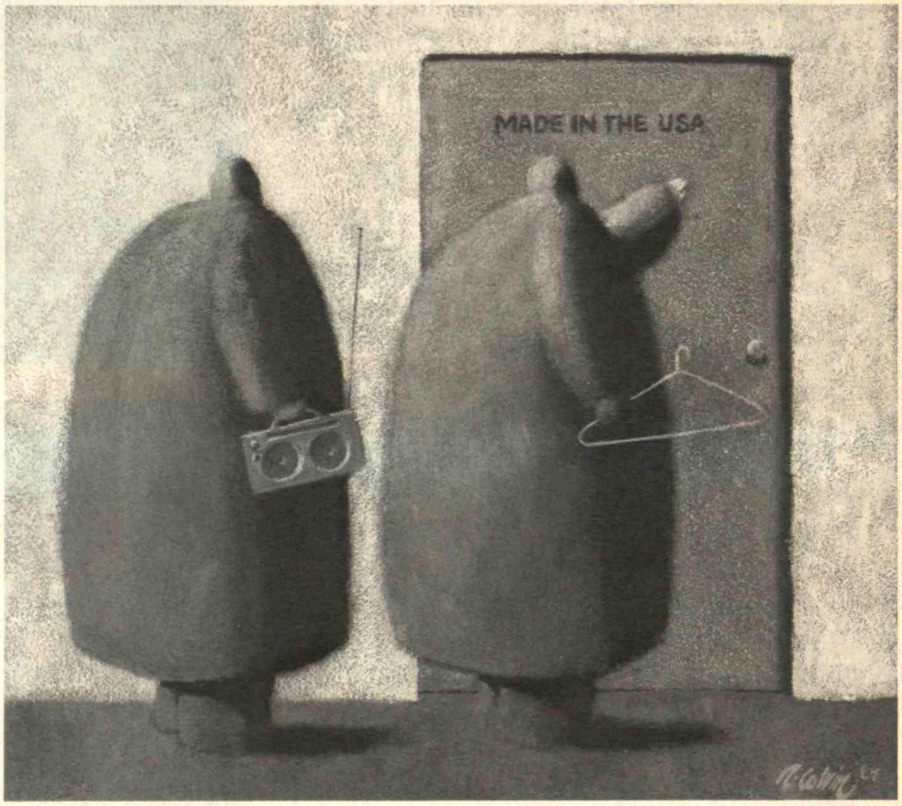
Bringing Manufacturing Jobs Back Home

FINDING a gift that says "Made in U.S.A." is a difficult task these days. More and more goods sold in the United States are produced overseas, and while that may be a boon for American consumers in search of bargains, it has caused havoc among American industries and workers. American-made products are not only being driven out of U.S. markets; they are losing ground in foreign markets as well.

As Lester Thurow explained in this space last month, much of the difficulty stems from the high price of the American dollar compared with other currencies. But the overvalued dollar is not the only cause of our foreign trade problems. Plainly, foreign competitors are benefiting from more than just simple economics. After all, the United States had a balance-of-trade problem back in the 1970s even though the dollar was considerably weaker then. In many instances, foreign manufacturers have improved the quality of their goods and shown great imagination in style and design. Professional television cameras and home stereo equipment are two areas where this has occurred.

Under the circumstances, what can beleaguered American manufacturers do? The first task is to work for a weakening of the dollar. However, the value of the dollar is unlikely to decline as long as the U.S. government tolerates such a large budget deficit. A deficit of $175 billion to $200 billion requires heavy borrowing by the U.S. Treasury, which in turn keeps up interest rates. As long as interest rates are high, foreigners will continue to buy dollars to invest in American securities. The demand for those dollars will push up their value until investors decide to invest in more profitable opportunities elsewhere.

Even when the dollar falls—and some day it will, perhaps even by the time this article appears—many U.S. manufacturers will need to do something more to make their products competitive. The manufacturers of computers and electronic equipment have already acted by developing products technologically superior to those made abroad. As a result, they find ready markets in foreign countries despite the strong dollar and high labor costs.



MARSHALL GOLDMAN IS PROFESSOR OF ECONOMICS AT WELLESLEY COLLEGE AND ACTING DIRECTOR OF THE RUSSIAN RESEARCH CENTER AT HARVARD UNIVERSITY.

Money Plus Imagination

But that is not a solution for the majority of American manufacturers that produces more traditional goods. These makers must use increasingly sophisticated computer technology to automate their production processes in innovative ways. Simply automating assembly lines is not the answer; considerable thought must be given to how automation can be used to support human endeavor rather than diminish or replace it. Furthermore, automation must be applied more creatively to industries that depend heavily on hand labor and have already lost many production jobs to the developing world. The problem is that some production processes do not lend themselves easily to automation. Some tasks are too complicated to automate while others are expensive.

Yet American companies may well have an advantage in attempting to automate some of these difficult processes. That advantage is ready access to capital and experience in using sophisticated computers and robots. Capital is more readily available in the United States than elsewhere because investors worldwide feel secure about putting their money into American ventures, and because this country imposes fewer restrictions on the flow of money across its borders. Japan, for instance, is only beginning to loosen up on some rather strict limits on foreign investment in Japanese enterprises.

Here are two examples of what can be done with automation given imagination and capital. One is in apparel manufacture, which has moved an ever-larger share of production to the developing world because of the low cost of labor. The other is in the manufacture of car radios, in which the United States once had a significant lead that has now been eroded by the cheap-labor countries of Asia and the Southern Hemisphere. As different as these industries are, their efforts to bring production back to the United States have much in common.

The problem for American manufacturers of apparel is that so much of the

ILLUSTRATION: ROB COLVIN

cost results from hand labor. That's because no one has figured out how to automate the sewing and assembly process, which requires 100 to 150 separate operations in the case of a man's suit. Automating even a single process is difficult because almost all steps involve the manipulation of limp fabric, a task that is much more difficult than handling a piece of wood or metal. The apparel industry is also notorious for its reluctance to invest money in research. Companies have chosen instead to lower costs by seeking cheap labor to operate simple sewing machines.

The only hope for the garment industry is to resist this short-run temptation and invest in ways to change the production process. With this in mind, two Harvard Business School professors, John Dunlap (former secretary of labor) and Frederick Abernathy set up a consortium representing the Amalgamated Clothing and Textile Workers union, several textile companies, and apparel concerns. This group approached the National Science Foundation in 1979 to obtain funding for an automation study. With a subsequent grant from the Department of Commerce, they then went to the Charles Stark Draper Laboratory in Cambridge, Mass. Although Draper Lab primarily designs guidance systems for weapons and space vehicles, its people know how to manipulate computers and microprocessors in a way that is matched by few other research facilities in the world.

The consortium's bold strategy has apparently paid off. In 1983 Draper Lab successfully field-tested a prototype of an automated sewing system that can produce men's sleeves and suit backs. The project has been expensive: Congress has already appropriated 3.5 million dollars to see it through the developmental stage. Even with this support, a single sleeve-making machine will cost as much as $100,000. However, the system should be available for commercial use in 1986, enabling U.S. manufacturing firms that can acquire this system to compete again with anyone, regardless of the cost of American labor.

Flexible Automation

The car radio industry faced similar concerns. While 90 percent of the radios installed in American automobiles used to be U.S.-made, that figure dropped to 80 percent by the late 1970s and has continued to fall. Some of this decline is due to poor service, but most stems from the fact that cheaper models are available from abroad.

Delco, a subsidiary of General Motors, adopted a two-pronged strategy in an effort to retain its share of the market. First, it too began production in the low-cost labor markets of Singapore and Mexico. Second, the company decided to automate its main plant in Kokomo, Indiana. This effort required a more flexible working relationship with the union. Realizing that future jobs were on the line, the union agreed to permit the installation of up to 150 robots to perform assembly functions that no one had been able to automate before. Only a sophisticated mix of computers and robots has made this possible. When this new production line finally opens in a year or so, it should once again make Delco's Indiana operation competitive with overseas production and, Delco hopes, prevent the loss of even more jobs.

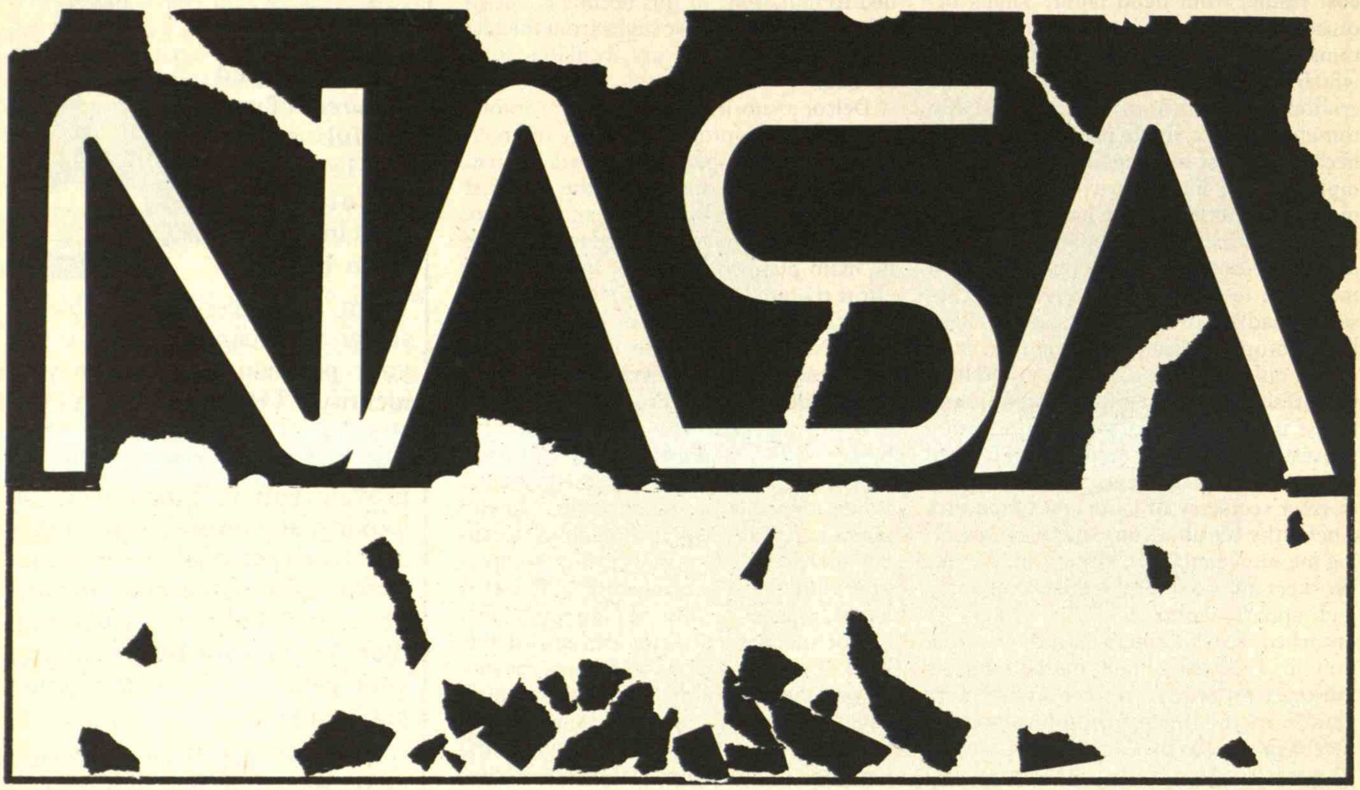
Not many small firms can afford this kind of investment. But the apparent success of the apparel industry's consortium suggests that joint research ventures may be a way for small companies to reap the benefits of innovation. Unfortunately, automating production does mean the loss of some jobs. If the U.S. apparel industry converts to the automated system developed by Draper Lab, about 20 percent of its workers will lose their jobs, according to Murray Finley, the president of the Amalgamated Clothing and Textile Workers union. But the garment unions have come to realize that as painful as that may be, automation will prevent the loss of even more jobs. The locals of the United Auto Workers who are involved in radio assembly have gradually come to the same realization.

Of course, manufacturers in other countries may eventually try to copy U.S. automation technology if it is successful. And those who follow the leader often are able to learn from the forerunner's mistakes and accomplish the same task more cheaply and even more efficiently. But that does not mean we should avoid the effort—only that once we master a new process we should not rest on our success, as we all too often do. Given its comparative advantage in obtaining access to capital and "cutting-edge" technology, U.S. industry is certainly capable of being competitive, but it will take effort, imagination, and persistence. □

FORUM

BY WILLIAM LASSER

The Manned Space Station: NASA's Last Hurrah?



WITH a big push from President Reagan, the National Aeronautical and Space Administration (NASA) succeeded last year in persuading Congress to authorize funds for establishing a permanent manned space station. Approval of the project was a big victory for NASA over critics who argued that the money would be better spent on unmanned scientific endeavors or military projects. Ironically, though, NASA's victory in the space-station struggle and the way it was achieved point to a cloudy future for the nation's civilian space agency.

President Ronald Reagan acknowledged NASA's lobbying efforts when he included a call for the space station in his 1984 State of the Union address. From NASA's point of view, the president's proposal was a major success: $150 million in startup money was included in the almost $300 billion defense budget, approved by Congress in late June. The president, however, was convinced as much by the political benefits of making such a proposal as by the scientific and commercial advantages of operating a space station. And as a political gesture the president's call for a space station was a complete failure—a failure that may signal serious trouble ahead for NASA.

Reagan's call for establishing a station "within the decade" was certainly modeled, consciously or unconsciously, on President Kennedy's 1961 speech in which he pledged to land an astronaut on the moon. This challenge energized a nation that seemed temporarily to have lost its self-confidence and sense of purpose. Kennedy's call came at a time when his young administration faced a serious crisis of confidence. The nation was still reeling from the Bay of Pigs disaster, the Cold War was raging, and communism seemed to be winning on several fronts.

It was in this atmosphere that JFK spoke to the nation. He seized upon the space issue to unite the country and create a sense of purpose. The moon landing was to be more than just a technical or scientific achievement; it was part of the "battle that is going on around the world between freedom and tyranny," part of "the battle for men's minds." America had to be first in space to show the world that democracy and capitalism were superior to tyranny and communism. Kennedy pledged that when the first U.S. astronaut landed on the moon, "it will not be one man going to the moon—it will be an entire nation."

Just Another Budget Item

The Mercury, Gemini, and Apollo missions kept Americans riveted to their television sets throughout the 1960s, providing the one source of untarnished good news in that troubled decade. Most Americans seemed to respond to the proposition that they could accomplish great feats in peace as well as in war.

Unlike Kennedy's challenge, Reagan's proposal was designed to have more than just symbolic importance. "A space station will permit quantum leaps in our research in science, communications, and in metals and lifesaving medicines," Reagan declared. "Just as the oceans opened up a new world for clipper ships and Yankee

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ILLUSTRATION: ELIZABETH SLOTE

If the public continues to show indifference toward space, future presidents may be reluctant to keep NASA alive.

traders, space holds enormous potential for commerce."

Still, the practical advantages of the space station are only one part of the package. Reagan called on the nation "to build on America's pioneer spirit" and develop "the next frontier." In words that could have been JFK's, Reagan defined the broader purpose of the mission: "Nowhere do we so effectively demonstrate our technological leadership and our ability to make life better on Earth. Our progress in space—taking giant leaps for all mankind—is a tribute to American teamwork and excellence. Our finest minds of government, industry, and academia have all pulled together, and we can be proud to say: we are first, we are the best, and we are so because we are free."

But in contrast to JFK's clarion call, President Reagan's proposal has been all but forgotten in the year since his State of the Union message. The discussion of the space station turned into a dry debate within the government and the scientific community over whether a permanent station represented the best use of the limited resources the United States has to expend on space science and technology.

The space station was strongly supported by the NASA but was just as strongly opposed by other government agencies. The Central Intelligence Agency and the Department of Defense feared it would draw money away from their own programs. Frank Press, president of the National Academy of Sciences, commented that basic research in science would not "require or be enhanced by the space station." In fact, many scientists feared that the station would hurt basic research by soaking up government money. "An \$8 billion project," said one, "can wipe out lots of \$100 million projects."

Why was Kennedy's proposal an inspiration and Reagan's only another budgetary proposal to be hashed over by a few lobbyists and members of Congress? For one thing, Americans have been spoiled by success. The space shuttle routinely orbits the Earth and comes back like an ordinary airplane. The idea of a manned space station—which 20 years ago was the stuff of science fiction—is now viewed simply as a realistic but not particularly exciting policy option.

The daring exploits of the astronauts and scientists aboard the shuttle do seem to have sparked the public's interest in space again. NASA has accomplished this public-relations feat only by playing up a number of "firsts"—the first woman in space, the first woman to walk in space, the first satellite rescue. But it will not be long before these accomplishments fade into a dull routine.

More important, perhaps, America's attitude toward science has itself changed fundamentally. In the early 1960s science was equated with progress; technological advance was seen as an end in itself. "A nation's prestige," said then Vice-President Lyndon B. Johnson, "is measured by . . . its achievements, or lack thereof, in space." Americans in 1984 see the world differently. We are more conscious of the fact that science and technology can cause problems as well as solve them. Most Americans in 1961 were blissfully naive about the possibility of nuclear war. They had yet to confront the environmental problems that accompany economic and industrial progress. And they were only beginning to face the ethical and social problems caused by advances in biology and medicine.

For NASA, all this is bad news. The agency has always depended on the excitement of space travel—and on politicians' exploitation of that excitment—to obtain funding for its expensive programs. Both the moon-landing project and the space shuttle depended on public support for continued funding, and NASA depended on both projects to justify its own existence as *the* government agency in charge of space exploration and development. If the public continues to show the kind of indifference accorded Reagan's proposal, future presidents may be reluctant to commit the resources necessary to keep NASA alive.

Big Bucks in Space

Meanwhile, NASA faces a more immediate challenge: the growing interest of the private sector in space commerce. Private launch services are already competing with the shuttle for transporting research and manufacturing projects into space. NASA has so far managed to keep its shuttle prices down by subsidizing each launch to the tune of \$71 million. But if the agency is forced to discontinue that subsidy and shuttle prices rise to reflect the true costs involved, high-tech companies interested in space manufacturing may turn to private services.

McDonnell Douglas and Johnson & Johnson have projected that their space-based pharmaceuticals processes will be producing sales of \$1 billion per year by the mid-1990s. And Rockwell International recently estimated that the sales of space-produced semiconductors and high-purity glasses would reach \$10 billion annually in the 1990s. Such manufacturing activities would probably involve the shuttle, which by then may be operated by a private company; the space station; and space platforms leased by private firms.

Given such commercial potential, the aerospace industry may well prefer private rather than public financing for the space station. If private-sector enthusiasm remains high, NASA may soon have to justify its role in the construction of the space station. Why not just let private investors build the pieces of the infrastructure as needed—and as they become profitable? NASA officials argue that a permanently manned space station is far too expensive and risky a project for private investors. They point to the U.S. government's history of taking the lead with "cutting-edge" projects. Such issues will no doubt be raised this year when NASA's fiscal-1987 budget request for the space station approaches \$1 billion.

Even if NASA obtains the requested funding and remains the project's primary developer, what will happen when construction is finished around 1992? At that point, the station will probably be leased to private companies and other federal agencies, with NASA retaining control. However, such arrangements may not last long: there's a good chance that several space stations will be built and managed by different agencies and private firms.

NASA may then have to convince a future president to lead the way on some other glorious project in space— perhaps a permanent base on the moon (*see "Shackling Lunar Developers," page 6*). Of course, by then public interest in space may reignite; for example, the discovery of extraterrestrial intelligence would certainly prompt a dramatic swing in public opinion. But if the interest of the majority of Americans continues to decline—as it has since the days of Apollo—then a future president may be reluctant to expend massive funds on space exploration. And if that happens, NASA may see its functions divided up among other government agencies and the private sector. For the first time, the agency may face a struggle for its very existence. □

Down to the Sea in Print

LIKE most engineers, I receive many unsolicited bulletins and announcements in the mail. These folders, cards, and booklets come in a variety of shapes and sizes. Scarcely a week goes by in which I do not learn of a meeting, seminar, course, or symposium that I might profitably attend. I am often tempted by these opportunities to expand my intellectual and social horizons, but practical considerations usually keep me at home.

Nevertheless, I have always read this literature with an intensity that I find difficult to explain. I suppose that in browsing through schedules and scanning the titles of lectures I expect to learn something by osmosis. Also, it is comforting to know a bit about what is "happening" in the profession, even if the details remain obscure. Whatever the reason, these mailings afford me plenty of interesting reading.

Recently, however, I have found this pastime less enjoyable than before. The change is related to the nature of the events being planned: the ubiquitous computer has taken over. Almost every gathering of technically trained people appears to be devoted to modeling, simulation, imaging, or optimization. Even in my own field of civil engineering the emphasis is on the application of computers to drafting, estimating, and design.

I do not want to stand in the way of progress, but I am uneasy about the growing perception that all our problems will yield to the application of electrons and microchips. An information explosion is not a real explosion; it does not blast rock for making tunnels or building foundations. The most brilliantly conceived computer will not raise crops, dispose of toxic waste, or repave highways.

Occasionally, to be sure, I receive notice of a meeting devoted to large-scale engineering, but these have become relatively infrequent and even these seem to be less buoyant and full of promise than they used to be. Instead of new projects and techniques, they deal increasingly with structural failure, the problems of government regulation, and the rising cost of malpractice insurance. A recent seminar on the infrastructure crisis featured as many papers by politicians as by engineers. The problems with the infrastructure, of course, lie less in technologies—which are mostly ready at hand—than in politics, where shortsightedness holds sway. The conference was an invitation to frustration and despair.

SAMUEL C. FLORMAN, A CIVIL ENGINEER, IS AUTHOR OF ENGINEERING AND THE LIBERAL ARTS, THE EXISTENTIAL PLEASURES OF ENGINEERING, *AND* BLAMING TECHNOLOGY.

The deluge of mail reveals insights about new technological frontiers.

And so it has been for several months now. Between the breezy promises of the electronic wizards and the often depressing problems inherent in macroengineering, my pleasure in reading about meetings has been greatly diminished.

There are a few exceptions. A program on automated people movers piqued my interest, as did others in biomedical engineering, quality in instruction, and nondestructive testing materials.

But one of the exceptions has made all the difference. On a cold winter's day there arrived, unbidden, notice of an Offshore Technology Conference scheduled to take place in the Houston Astrodomain. I have no more experience with offshore technology than with electronics, but nevertheless the brochure gave me a lift. For one thing, the cover, instead of showing the pattern of an integrated circuit—a symbol of which I have grown exceedingly weary—featured a painting of the open sea, whitecaps breaking against an oil-drilling platform in the middle distance. Visions of the sea are enough to start anyone's pulse racing.

I do not usually think of oceans in terms of engineering, but obviously this reflects my own limited horizons. As I learned from this slim booklet, the Offshore Technology Conference has been held annually since 1969 and is currently sponsored by 11 professional societies representing more than 600,000 engineers.

The variety of subjects to be discussed at the conference was dazzling. One session was devoted to the dynamics of offshore structures, others were devoted to foundations, platform construction, mooring, and anchoring. Lectures were planned on seabed mapping and soil testing, seismic and sonar surveys, wire rope, anchors, chains, and hawsers, as well as erosion, abrasion, metal fatigue, and corrosion, not to mention deep-water drilling, welding, and tools for divers. The disciplines covered included marine geology, arctic operations, the analysis of wave forces, and the study of ice.

Most of the announced participants were affiliated with the oil industry, as expected. But one session was allotted to "Marine Minerals Mining" and the lecturers came from institutions I didn't even know existed: Minerals Management Service, Lockheed Advanced Marine Systems Division, and the University of Petroleum and Minerals in Dhahran, Saudi Arabia.

I pored over this captivating program for a long time, as it told me much about engineering activities to which I had previously given very little thought. Of course, many such catalogs promise wonders that turn out to be disappointing. Has the time for ocean engineering truly arrived, I wondered, or is the field—aside from offshore drilling for oil—still in the stage of dreams and hype?

I do not know. But I do know that if I were starting my engineering career today, I would be greatly tempted to look to the oceans. They are truly our next frontier. Their allure and the challenges they pose are unparalleled. At least this is the way I feel after looking through the program with the seascape on the cover. Who knows what the mail will bring tomorrow? □

ILLUSTRATION: KEN CONDON

KODAK ANNOUNCES THE LARGEST FAMILY GET-TOGETHER IN HISTORY.
AMERICA'S FAMILY ALBUM.
It's where Kodak will bring together millions of family photos from across the country. All to become part of a historic exhibit at the Statue of Liberty National Monument. An electronic photo exhibit that will begin in July of 1986. And will remain for years to come.
How you can be a part of it.
Simply send Kodak a picture of your family; a treasured old favorite or a photo you've just taken. You'll receive a certificate to display. And an I.D. card to help locate your picture at the exhibit.
How you'll help save a great lady, too.
We've pledged our support for the restoration of the Statue of Liberty and Ellis Island. Your check and photo will help us fulfill that pledge.
So send us your picture and be a part of this historic get-together. For the future generations of your family. For the American family. For one of the greatest ladies in our history.
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For additional coupons, see your photo retailer.
I WISH TO PARTICIPATE IN AMERICA'S FAMILY ALBUM.
I enclose a check/money order for $10, along with my family photograph. I understand this photograph will not be returned to me and will be part of a public exhibit. (Please Print)
Name
Address
City State Zip
Telephone ( ) Birthdate
Principal Family Name in Photo:
Country of Origin:
Year of first entry into U.S. (if known):
Year & Location of Photo. Year:
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Your participation will help Kodak meet its pledge to restore the Statue of Liberty.
NOTE: You may submit as many photos as you wish, but 1. Photos (prints only) must be no larger than 8" x 12". 2. Each photo must be accompanied by a separate entry coupon. If several photos are submitted, be sure each is identified. Simply tape coupon to back of each photo. Do not staple. 3. Include $10 check or Money Order for each photo. If several are submitted, write one check for total amount. 4. Kodak not responsible for lost, torn or mutilated photos. Protect photos between cardboard inside mailing envelope. We suggest you send duplicate prints only, which can be supplied by your photo retailer. 5. Kodak reserves right not to accept photos deemed obscene or otherwise unsuitable. In such case, your money will be refunded only. 6. Payment must be submitted with photo to be included in Album. 7. You'll receive your membership certificate and an ID card to help locate your photo. Allow 8 weeks for delivery. 8. Non-members will also be welcome at the exhibit. 9. Offer expires December 31, 1986.
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Innovation, Workers' Health, and Urban Architecture

Stoking the Fires of Innovation

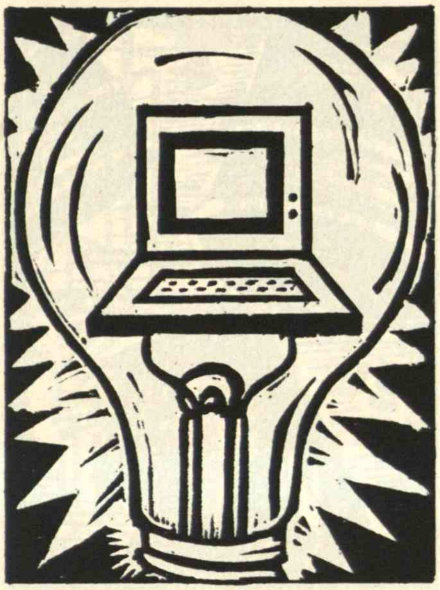
Fire in the Valley:
The Making of the Personal Computer
by Paul Freiberger and Michael Swaine
Osborne/McGraw-Hill, $9.95

Reviewed by Mel Horwitch

The intensely competitive global environment has led to the recognition that technology should be a major element of corporate, as well as national economic, strategy. But our understanding of the complex chain of activities that leads to significant new technology is still woefully inadequate. Developing modern technology seems to depend on an array of key factors that cannot be easily identified, explicitly generated, or systematically managed. However, analyzing the history of technological success, in all its diversity and subtlety, can yield important strategic lessons.

Fire in the Valley, a fast-paced, thorough study of the early personal-computer industry, allows us to do just that. This sector, of course, has today become almost synonymous with high technology generally. Authors Paul Freiberger and Michael Swaine seem to have interviewed practically everyone of consequence, and thus are able to convey the atmosphere and spirit of the personal computer's fledgling days.

The authors show that the industry actually developed in two stages. The first, from the mid- to the late-1970s, saw the birth of pioneering firms such as MITS, Processor Technology, and IMSAI. These companies ultimately failed or were soon eclipsed by other firms. But before this first decline occurred, the industry was as exciting and experimental as any in American history. Freiberger and Swaine are especially good at describing the idiosyncracies of the firms' founders, including Ed Roberts of MITS, Bob Marsh of Processor Technology, and William Millard of IMSAI. Their efforts at innovation revealed the classic weaknesses of high-tech entrepreneurialism: a lack of financial resources, appropriate business skills, the ability to keep up with demand, and the skill to manage all the elements of the innovation process. However, although none of these entrepreneurs put it all together strategically, sometimes because of counterproductive personality quirks, they often later went on to successful careers in other segments or firms in the industry. And their experiences paved the way for the second period of personal-computer firms that appeared in the late seventies.



Apple, of course, is the preeminent success story from this period. Its leaders combined unique technical prowess (embodied in the person of Stephen Wozniak), tremendous drive and ambition (embodied in the person of Steve Jobs), sound business decisions regarding customer needs and dealer support, and probably a hefty amount of luck as well. A few larger, more established firms also began to discern the opportunities in the personal-computer industry. Commodore International entered the fray from a position of manufacturing strength and vertical integration, and therefore competed effectively via economies of scale, low cost, and high volume. And Radio Shack-Tandy skillfully used its tremendous distribution network to become a major force in the industry. As Freiberger and Swaine show, executives within both these large firms showed much insight and took many risks in their willingness to compete at this stage.

Home-Brewed Technology

An infrastructure that enhanced the appeal of the hardware proved crucial to the industry's success. Accessible software was the first requirement, and the authors make the saga of Bill Gates, who founded Microsoft, as exciting as that of the hardware entrepreneurs. They further point out that credit for much of the Apple II's success must go to VisiCalc, the revolutionary, easy-to-use spreadsheet program that at first was available only on an Apple disk. Personal-computer magazines also played a major role in spurring the industry's growth, as did computer shows for the general public, which unexpectedly attracted huge audiences. And operators of the first retail stores, such as Dick Heiser of The Computer Store and Paul Terrell of The Byte Shop, created legends every bit as colorful as those of the hardware producers.

However, the most important element in the infrastructure of the early industry was the sharing of technical advances among hobbyists. Computer clubs, particularly the Homebrew in the Bay Area of northern California, served as the arena where the counterculture of the 1960s could mingle with the computer enthusiasm and high-tech entrepreneurialism of the 1970s. Certainly this sharing environment was as effective in rapidly diffusing microcomputer knowledge as any MITI-led program in Japan.

Freiberger and Swaine create a kind of paradise lost in describing this era. Some visionaries such as Lee Felsenstein, a leader of the Homebrew and designer of the Osborne portable computer, strived to create computers and software for the people. Other hobbyists such as Steve Jobs emerged from the counterculture to become full-blooded entrepreneurs who unabashedly sought fame and fortune.

The helter-skelter fun and excitement of this era was fast disappearing by the early 1980s as the stakes grew higher. The entrance of IBM into the market in 1981 and the failure of the Apple III marked this change. Ironically, now for computers to be used by "the people," large corporations (including, by now, Apple) will have to provide them.

The history of this industry raises the question of whether large firms can consistently stimulate high-tech entrepreneurialism. IBM competed by creating an Independent Business Unit to develop its PC, mimicking the small-firm environment. Now that this unit has become a division, it has encountered problems with later products, particularly the PC Jr. Whether small firms can maintain their identity while tapping the marketing and

manufacturing clout of large firms, in today's era of joint ventures, equity agreements, and corporate venture capital, is also uncertain. Much of the vitality of this industry was due to the coexistence of both small-firm entrepreneurialism and large-corporation innovation and R&D, as Freiberger and Swaine illustrate.

This experience shows that a sharing, informal environment, creative people, and a set of networks can provide the complexity and variety that allow continuous technical learning to occur. Under today's heightened competitive pressure, as we attempt to become more efficient, explicitly strategic, and professionally managerial in all types of technology-based businesses, we may be in danger of losing the early spontaneity that has led to such astounding success. □

MEL HORWITCH, an associate professor in the Corporate Strategy Group at M.I.T.'s Sloan School of Management, is author of Clipped Wings *(M.I.T. Press, 1982), a study of the American supersonic transport program.*

Protecting Workers' Health

Workers at Risk
by Dorothy Nelkin and Michael Brown
University of Chicago Press, $20

Reviewed by Chris Anne Raymond

When I was a child, my father would come home from the steel plant covered in orange dust, his shoulders drooping from eight hours of exposure to heat and heaving metal. As my mother dutifully set out his clean clothes, cracked open the beer, and heated and served the leftover roast, he would tell her about the day's events in tones as fiery as the plant he had just left. Yet I only dimly understood that taking orders and making filthy ore gleam was what brought him home so dirty, angry, and thirsty. Occasionally he carried news of an accident—a broken leg, a fatal fall—and for the next few days my mother's so-long embrace would be a little more intense.

By the time I was in college and my father worked in the company's sintering

plant, I understood all too well that in exchange for better wages, my father's lungs were being attacked by the same orange grit that ate away the paint on the Buick he drove to work. The plant's closing in 1983 was a tragedy for many, but my family considered it a blessing: my father escaped one of the dirtiest jobs anyone could have with his health intact.

These memories are now filtered through years of acting out my parents' dreams of graduate school far removed from the grime and grit of blue-collar work, years of my father's protective silence about the dangerous realities of his job. He and my mother hoped their children would escape his fate.

Dorothy Nelkin and Michael Brown's *Workers at Risk: Voices from the Workplace* stirred those childhood memories. By allowing more than 75 workers whose jobs expose them to chemicals to talk about their experiences, the authors give new voice to life on the shop floor. There is Ken, the electrician at a chemical plant, whose initial devil-may-care attitude about safety is replaced by constant worry at work and at home about the chemicals he handles. Don, the railroad conductor, wonders if his daughter's cancer was caused by the dioxin used to keep the tracks clear of undergrowth, some of which he carries home on his clothes. Kitty, the painter, tries to prove herself to male coworkers by brazenly soaking her hands in epoxy. Dorothy, a deckhand on a ship, realizes that a coworker below deck has passed out from paint fumes only when his arm stops moving. Sociologists Nelkin and Brown also interview workers in museums, beauty shops, research labs, and computer-assembly plants—places where few people would guess employees are exposed to toxic chemicals.

The authors organize these tales according to fears and anxieties, illnesses and complaints, attributions of blame, coping strategies, and courses of action. The workers' comments poignantly express their situation: "I guess everybody will get it sooner or later. If you're gonna get it, you're gonna get it," and "You never balance the wage against the risk; you balance the wage against the alternative. And the alternative is starving." One key insight that emerges from these comments is that there is no direct link between actual hazards and people's perceptions of risk. Artists and research scientists often feel that the rewards of their job outweigh the risks of handling extremely toxic chemicals. Because they lack these same rewards and control over their job, lab technicians and assembly-line workers often perceive far greater risks from handling the same substances. The workers' testimony also implicitly highlights the class nature of health, since those higher up on the occupational, and hence socioeconomic, ladder often suffer far fewer work hazards.

These individuals' experiences underscore the cavalier way new products and the chemical processes on which they are based are routinely adopted with little thought for workers' health. Throughout *Workers at Risk,* employees complain that they lack information about the chemicals they deal with: they don't know their composition, immediate effects, or long-term and synergistic effects. The problem is that little such information exists.

Hundreds of chemicals are introduced annually with little systematic testing of their carcinogenic and neurological effects. This occurs despite passage of the Toxic Substances Control Act in 1976, which mandated that chemicals be monitored and controlled throughout their life cycle—from extraction and development through production and sale. Soon after the act became law, the Interagency Testing Commission identified 45 individual or classes of potentially hazardous chemicals to which thousands of workers are exposed, but for which little toxicological information exists. However, just a hand-

Despite centuries of effort, our cities remain a jumble of architectural visions.

ful of these chemicals has since been controlled, and then only after lengthy and costly litigation with industry.

Why this disregard for workers' health? The problem is not one of feasibility. Corporations and governments routinely collect intricate financial and political data about their competitors and citizens. Rather, the issue concerns our society's priorities. Firms pursuing short-term profits often neglect long-term consequences in both the workplace and the environment. They can pass off the external costs of cleaning up polluted streams and treating sick workers to the public debit sheet.

Many European nations devote far greater resources than does the United States to inspecting workplaces and monitoring workers' health. For example, Italy has required control of 47 hazardous substances since 1952. There workers do not have to prove a cause-and-effect relationship between toxic exposure and disease; simply the presence of a hazardous substance in the workplace is enough for victims to receive compensation. In Finland, the ratio of local occupational health inspectors to workers is 1 to 4,440; in the United States, 1 state inspector monitors every 20,000 workers under the purview of the Occupational Safety and Health Administration.

The form of Nelkin and Brown's book is both its strength and its weakness. While the workers' comments evoke sympathy for those who bear the burdens of profit making, their testimony does not enlighten us as to which conditions evoke passivity and which stimulate action. Without such information, determining how health concerns can become a priority on the shop floor and in the community is difficult. Occupational health is essentially an issue of workplace control. As a stage carpenter says, "The only adequate safeguard is to have the people who are exposed to the hazard, the workers themselves, be substantially in control of their circumstances, their physical surroundings, and the priorities involved in their work." The question is how to unite workers across industries and communities to help make that goal a reality. □

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The Idea of the City

Collage City
by Colin Rowe and Fred Koetter
M.I.T. Press, $9.95, paper

Reviewed by Tarek Ashkar

The city has always been a collage of intentions. Despite centuries of effort and artifice by architects and urban designers to create illusions of clarity and order, our cities remain a jumble of architectural visions. *Collage City*, first published in 1979 and recently issued in paperback, attempts to elevate this real situation to the level of an ideal. Authors Colin Rowe and Fred Koetter call their book "a program for constructive disillusion." It is a critique of the modern architect's optimistic vision of a completely ordered and designed city of the future.

The authors' ideas have descended from their academic plane to become some of the major tenets of post-modern architecture. We see their ideas affecting practice every day, from the current boom in restoration and historic preservation to the landmark rewriting of the Manhattan zoning laws to preserve the character of Fifth Avenue. At the root of these events are changing architectural ideals that prefer the incident to the grand gesture, the eclectic to the pure. The new sensibility is more attuned to accommodation and collage than to the ideals of clarity and order.

According to Rowe and Koetter, architects' concept of the ideal city has long been based on contemporary notions of the ideal society, or utopia. However, these notions have changed over time. Until the eighteenth century, utopia harkened back to antiquity—an idealized, classical past. Architects' drawings of the ideal city were primarily symbols of that perfect society. Their geometric urban plans, often based on polygonal forms and resembling cosmic diagrams as much as cities, reflected the static hierarchies of the princely state.

With the Enlightenment, the Golden Age moved from an emphasis on idealized antiquity to the literal future, and the ideal city came to be seen as a tool for social betterment. During the nineteenth century, in which society was viewed as an evolving organism rather than a fixed order, architects' ideal city changed from static, closed geometries to more open and organic compositions such as Arturo Soria's design for an endless, curving, linear city. The role of architects was transformed as well: liberated from the bonds of royal servitude, they became self-proclaimed social servants, visionaries burdened with the task of pushing society into the future.

The modern movement of the early twentieth century inherited the previous era's utopian fervor as well as its romanticized view of the architect. But the ideals of technology and the machine replaced the changing social order as the historical force that could not be resisted. Le Corbusier dreamed of leveling much of Paris to make way for a vast park dotted with skyscrapers and criss-crossed by highways. However, as the authors note, modern architecture's urban vision was an all or nothing proposition—a vision of change so all-encompassing that it was impossible to bring into existence. The contemporary embodiment of this ideal, the glass tower surrounded by a plaza, remains a fragmentary image.

In the past couple of decades, some critics have castigated modernism for not going far enough, in either its social agenda or its romance with the machine. Others have reacted by casting their lot with the "people" in an unqualified embrace of their traditions. The results are vernacular English "new towns" that incorporate a vision of Old World charm usually represented by pitched roofs, market squares, and awnings—all of which create the feeling of being on a stage set.

Architects as Tinkerers

To resolve this contemporary impasse, the authors propose that the ideal city need not be ideal. Rather, today's urban areas can accommodate a variety of utopian notions, including tradition and futurism and whatever lies in between. The city may both recall the past and prophesy the future. And in place of the role of the architect as visionary, the authors propose the "bricoleur," a figure they borrow from Claude Levi-Strauss that means putterer or tinkerer.

With utopia neutralized and architects dethroned, Rowe and Koetter put forward their own vision of the city as reflected in numerous models. These include early nineteenth-century Paris and Munich, which possessed a museumlike diversity of architectural styles and monuments. The authors also propose Hadrian's Villa at Tivoli, constructed during the early Roman Empire, as an example of an agglomeration of building types with no immediately apparent structure or order. But the most successful model for a "collage city" is the technique of collage itself, in which the meanings of various objects are transformed by their artful relationship. Rowe & Koetter look to the work of Picasso and Braque for examples of this technique.

Collage City is a difficult book: the authors include such an assortment of ideas that readers may wonder whether they are confronting history, theory, or manifesto. And this breadth of topics is frequently not matched by a depth of treatment. Thus, architects may be confused as they shuttle through a somewhat flippant history of nineteenth-century social theory, while historians may be shocked by what passes for social theory among architects. City planners will be insulted on numerous occasions, and amateurs' heads will swim with the jargon of numerous disciplines in a book that ideally should be readable by everyone.

Collage City is a speculative work that makes suggestions rather than statements. The authors use a prose of persuasion that is sometimes exasperating in its vagueness: the book *is* a manifesto, but without the usual call to arms and threats of doom if its prescriptions are not followed. Yet, for many architects of the current generation, *Collage City* and the other teachings of its authors have been very convincing. The fact that contemporary architecture has begun to accommodate itself to the existing city, rather than wishing it away, can be traced directly to their influence. □

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Continued from page 5
pan and Taiwan, and I doubt these specialists will do path-breaking work.

Clearly, Singapore is not content with its strategy of using the work of others and is looking to become an innovator itself. However, without scientists and advanced engineers, implementing such a strategy will be difficult.

More Computers in the Classroom

In "Computers Are Sprouting in the Groves of Academe" (*October, page 18*), Peter Gwynne points out that students at Stevens Institute of Technology were required to purchase the Atari 800 computer in 1982. He then maintains that these students were "stung by the speed of technical advance" when the school began requiring them to use Digital's Professional Model 350 computer. Stevens is committed to integrating both these computers into the curriculum. We support development of courseware for juniors owning Ataris while we engage in projects involving the Digital PRO350 in freshman and sophomore classes.

This year, juniors in the Stevens science curriculum perform sophisticated calculations for quantum chemistry on the Atari 800. These students had the benefit of using numerical methods to solve differential equations as freshmen and performing simulations in a statistics course as sophomores. They now use their Atari machines, campus minicomputers, and mainframe computers with an uncommon facility that belies the assumption that they have a lingering need to "recoup" their initial investment.

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Energy from Hydrogen

James MacKenzie is correct in "Beyond Fossil Fuels" (*August/September, page 14*) that severe economic, political, and military repercussions will result when the next energy crisis hits. The heavy debt that now burdens many smaller nations is a direct result of the last energy crisis. The world must have a stable, clean source of energy to avoid catastrophe. Luther W. Skelton is also correct, in his book *The Solar Hydrogen Energy Economy*, which MacKenzie reviews, in identifying hydrogen as the only viable alternative to carbon-based fuels. At the 5th World Hydrogen Energy Conference recently held in Toronto, over 600 scientists and representatives from 34 countries, including the Soviet Union and China, expressed their concern about the serious threat that current energy sources pose to the environment and world peace.

I disagree with MacKenzie that government is a detriment in solving these problems. The Synthetic Fuels Corporation failed because there was no sense of national urgency regarding the need for developing a new energy source. The United States is capable of developing cheap solar hydrogen as that energy source. Needed are only adequate research funds and the enthusiasm mustered for the rapid buildup for World War II and the space race.

Most people continue to think of oil, coal, and natural gas mainly as sources of energy. But these precious resources are also raw materials for over 3,000 commercial products, including synthetic rubber, lubricants, medicines, plastic, and synthetic fibers such as nylon, Dacron, and polyester. What will happen when the raw materials for these products are no longer available?

If leaders of industry and their corporate shareholders would stop thinking only of short-term profits and give some thought to the future, we might develop that national sense of urgency and start building the solar-hydrogen infrastructure we desperately need!

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In vitro fertilization challenges such fundamental concepts as motherhood and fatherhood. Its possible uses raise troubling ethical questions.

Technology and Procreation: How Far Should We Go?

BY PETER SINGER

A revolution is under way in human reproduction that is comparable in many ways to the revolution in physics that produced the atomic bomb. But the reproductive revolution may prove to be even more far-reaching. If we succeed in averting nuclear disaster, new reproductive technologies may someday give us the power to reshape the human species itself.

The basic technology behind this revolution is in vitro fertilization (IVF)—fertilizing an egg outside the womb and transferring the resulting embryo back into the womb. Taken in itself, IVF may seem nothing more than a means of helping some infertile women become pregnant. But it opens the door to an avalanche of technologies that could be far more controversial: the freezing of human embryos for research use, the donation of an embryo from one woman to another, surrogate motherhood, sex selection, gene therapy for inherited diseases, and ultimately, genetic

ILLUSTRATIONS: MARILYN CATHCART

engineering of basic human traits.

Today, only six years after the birth of Louise Brown—the first human being to have been conceived outside a woman's body—some of these procedures are already possible. In Melbourne, Australia, the Monash University IVF team is currently storing some 200 embryos in liquid nitrogen at −196°F. At this temperature, they could remain viable for hundreds of years. Other IVF units, including one at the University of Southern California, are also using freezing techniques to store embryos.

Doctors at the University of California-Los Angeles Medical School have already employed the technique of embryo flushing. In this procedure, a woman is fertilized with sperm from the husband of an infertile woman. Then, within a few days of conception, the fertilized egg or embryo is flushed from her body and reimplanted into the infertile woman. So far, two births have resulted from the use of this technique at UCLA. Also, a growing number of infertility centers in the United States recruit surrogate mothers. For a fee, these women agree to be artificially inseminated with the sperm of a man whose wife is infertile. The surrogate mother then carries the fetus to term and relinquishes the child at birth to the couple.

No one has yet attempted to treat genetic disease in the womb by replacing a defective gene with a healthy one—a procedure known as gene therapy. And genetic engineering of basic human traits remains a distant possibility. But the first approved use of gene therapy in children after they've been born may be less than a year away. Scientists are already able to transfer genetic traits from one animal species to another—from rats to mice—with visible effects on the growth and development of the mice. With advances in reproductive technology occurring at a rapid pace, a "brave new world" is hard upon us.

Within this decade, or at most by the end of the century, we shall have to decide how to handle new technologies that call into question fundamental concepts such as motherhood and fatherhood and force us to ask which human qualities are the most desirable. We must start by acquainting ourselves with the new techniques and then decide which should become accepted practices in our society.

The original technique of IVF is well-known: a woman who can't conceive is given hormones to induce her ovaries to produce more than one egg during her next cycle. Her hormone levels are carefully monitored to detect the precise moment at which the eggs are ripening. The eggs are then removed, usually through a fine tube inserted into the woman's abdomen. The egg is sucked out up the tube. A laparoscope, a type of periscope illuminated by fiber optics, is also inserted into the abdomen so that the surgeon can locate the ripe egg. Instead of using a laparoscope, some IVF teams are now using ultrasound techniques that eliminate the need for a general anesthetic.

An IVF Baby Born Every Day

Once collected, the eggs are placed in culture in small glass petri dishes—not in test tubes, as popular belief would have it. Sperm are then obtained from the male partner through masturbation and placed with the egg. Fertilization occurs in at least 80 percent of the ripe eggs. The resulting embryos are allowed to divide once or twice in order to develop the embryos to the stage at which they would normally enter the uterus, via the fallopian tube. An embryo is then transferred to the woman some 48 to 72 hours after fertilization. The transfer, via the vagina, is a simple procedure.

It is after the transfer, when the embryo is back in the uterus and beyond the scrutiny of medical science, that things are most likely to go wrong. The majority of embryos transferred by even the most experienced IVF teams fail to implant in the uterus. The reasons for the high failure rate are uncertain. Even in natural conception, many embryos—perhaps as many as 75 percent—fail to implant. Dramatically improving the success rate of IVF may therefore not be possible. One pregnancy for every five transfers is now considered a good working average for a competent IVF team, and many newer teams fail to achieve anything like that rate. Nevertheless, so many units are now practicing IVF—including 70 in the United States alone—that several hundred babies have been produced as a result of the technique. According to one estimate, a new IVF child is now being born every day somewhere in the world.

Some people oppose this relatively simple technique even when used by a married couple. Certain religious groups object to IVF on the grounds that it is "unnatural," that it involves masturbation, that it is risky for the offspring, and that it separates the procreative and conjugal aspects of marriage and so

It is when the embryo is back in the uterus and beyond the scrutiny of medical science that things are most likely to go wrong.

damages the relationship.

We can deal swiftly with these objections. If we were to reject medical advances on the grounds that they are "unnatural," we would be rejecting modern medicine as a whole. The very purpose of the medical enterprise is to resist the ravages of nature that would otherwise shorten people's lives and make them much less pleasant.

The objection to masturbation stems from religious taboos of a previous era that most people, including clergy, would now consider outdated.

The claim that IVF is risky for the offspring may have been a strong argument before the technique became widely used. But results so far have happily refuted gloomy forecasts that the offspring would be mentally and physically defective. Of the several hundred babies born as a result of IVF, no more than two have had serious congenital defects. This is actually a lower rate than that for ordinary conceptions, and the defects are not believed to be the result of IVF. Of course, it is still too soon to claim with statistical certainty that the risk of defect does not increase with IVF.

The argument that IVF endangers the marital relationship is even more difficult to defend. Few infertile couples will take seriously the view that their relationship will be damaged if they use a technique that offers them the best chance of having their own child. In any case, it is extraordinarily paternalistic for anyone to tell couples that they should not use IVF because it will harm their marriage. That, surely, is for them to decide.

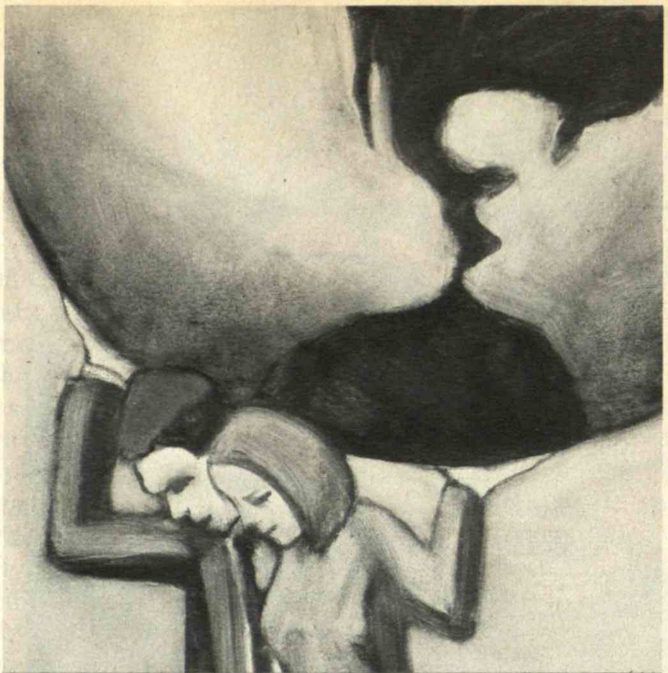
The Rights of Infertile Couples

Others argue that adoption is a better solution to the problem of childlessness than IVF. In an overpopulated world in which so many children cannot be properly fed and cared for, there is something incongruous about using all the ingenuity of modern medicine to create more children. Similarly, while so many people still die from preventable diseases, is there not something wrong with priorities that lead us to develop expensive techniques for overcoming the less serious problem of infertility? (Each attempt to fertilize and transfer an egg costs between $3,000 and $7,000.)

These objections would make sense in an ideal world where we would find loving families for all unwanted children, and where we could eliminate all malnutrition-related diseases before we tackled the problem of infertility. But is it fair to ask IVF alone to pass such a test? In an ideal world, none of us would consume more than our fair share of resources. We would not drive expensive cars while others die for the lack of drugs costing a few dollars. We would not eat a diet rich in wastefully produced animal products while others cannot get enough to nourish their bodies. We cannot demand more of infertile couples than we are ready to demand of ourselves. If fertile couples are free to have large families rather than adopt destitute children, infertile couples must also be free to do whatever they can to have their own children.

IVF also raises the question of whether infertile couples have a right to community medical resources. Again, we must not single out IVF for harsher treatment than we accord other medical techniques. If surgery to correct blocked fallopian tubes—the ducts that carry eggs from the ovaries to the uterus—is available and covered by health insurance, then why should IVF be treated any differently? Both techniques cost about the same. And if couples can obtain free or subsidized psychiatric care to help them overcome the psychological problems of infertility, there is something absurd about denying them free or subsidized treatment that could overcome the root of the problem. By today's stan-

dards, IVF is not an inordinately expensive medical technique. No country limits its provision of free or subsidized health care to patients whose lives are in danger. Once we extend coverage to less traumatic injuries, incapacities, and psychological distresses, IVF has a strong claim for inclusion among free or subsidized treatments.



We cannot demand more of fertile couples than we are ready to demand of ourselves.

A Boon for Women?

Some feminists have expressed concerns about the effects of this reproductive technology on the status of women. Robyn Rowland, an Australian sociologist, writes: "Ultimately the new technology will be used for the benefit of men and to the detriment of women. Although technology itself is not always a negative development, the real question has always been who controls it. Biological technology is in the hands of men."

I can see little basis for such claims. For a start, women have figured quite prominently in the leading IVF teams in Britain, Australia, and the United States. Jean Purdy was an early colleague of Robert Edwards and Patrick Steptoe in the research that led to the birth of Louise Brown. Linda Mohr has directed the development of embryo freezing at the Queen Victoria Medical Center in Melbourne, and in the United States Georgeanna Jones and Joyce Vargyas have played leading roles in the pathbreaking clinics in Norfolk, Va., and at the University of Southern California.

Even if we grant that this technology remains predominantly in male hands, we should remember that it was developed in response to the needs of infertile couples, and thus is as much a response to the needs of women as to those of men.

Rowland further argues that the development of more advanced techniques such as ectogenesis—the growth of the embryo outside the body in an artificial womb—will reduce the status of women. She concludes with the dire warning that "women's position is most precarious . . . we may find ourselves without a product of any kind with which to bargain. For the history of 'mankind' women have been seen in terms of their value as childbearers. We have to ask, if that last power is taken and controlled by men, what role is envisaged for women in the new world? Will women become obsolete?"

However, if ectogenesis ever becomes possible, I think it will provide a choice for women. As Shulamith Firestone noted in her influential work *The Dialectic of Sex,* such a choice would remove the fundamental biological barrier to complete equality. Firestone welcomed the prospect of ectogenesis and condemned the lower priority our male-dominated society gives to research in this area.

Firestone's view is surely more in line with the drive to equality between the sexes than Rowland's. If we argue that breaking the link between women and childbearing would undermine the status of women, we are questioning the ability of women to achieve equality with men across the broad range of human endeavor. I am not so pessimistic. I think women will be helped, rather than harmed, by the development of a technology that makes it possible for them to have children without being pregnant.

Thorny Ethical Questions

Other uses for IVF raise far more immediate ethical questions. For instance, a couple may not be infertile but may wish to use IVF because the woman carries a genetic defect. In that case, the egg would be donated from another woman, much as sperm are donated by another man when the husband carries a genetic defect. There's also the possibilty that both the sperm and the egg may come from other people. Finally, some of the embryos created may not be inserted into the woman's womb. Instead they may

be frozen and stored for later use, donated to others, used for research, or simply discarded.

Using IVF for fertile couples when the woman carries a serious genetic defect seems easy to defend. If we allow artificial insemination when the man has a genetic defect, we should also allow IVF when the woman is the carrier. Here too, however, there is a question of how far we should go. What if the defect is very minor? What if there is no defect at all, but the couple wants a donor egg or sperm from a male or female friend whose intelligence or beauty they consider superior to their own? A California sperm bank is already offering selected women the sperm of Nobel Prize-winning scientists. It is only a matter of time before "superior" eggs are also offered. Yet it seems clear that as long as IVF is not routinely available, those women who are infertile or who carry a serious genetic defect should have first claim upon it.

The use of donor sperm, eggs, and embryos raises further questions. One lesson learned from the use of donor sperm in artificial insemination is that a couple needs counseling before going ahead with the procedure. Psychological problems have resulted when one social parent is not genetically related to the child. The child, for instance, may feel a loss of identity and reject the social parent, particularly if he or she is going through a difficult phase. There is also the question of whether the child is to be told of her or his origins. Many adoptees believe they have the right to full information about their genetic parents; a strong case can be made that the same applies to people born as a result of the use of donor sperm or eggs. Non-identifying medical and familial information about the donor should be released to the parents so they can inform the child later.

Does an Embryo Have Rights?

The most controversial issue in this debate concerns the embryo's moral status. This is a crucial question when we consider whether to create more embryos than we are willing to put back into the womb at one time. Disposing of embryos or using them for research purposes runs counter to the view held by some that the embryo is a human being with the same right to life as any other. But religious doctrines apart, is it plausible to hold that the embryo has a right to life?

Those who claim that the embryo has a right to life make the fallacious assumption that mere membership in the species *Homo sapiens* is enough to confer that right. Why should species membership in itself be morally crucial? If we are considering whether it is wrong to destroy something, surely we must look at its actual characteristics, not just at the species to which it belongs. In terms of its actual characteristics, the newly conceived embryo ranks very low. Unlike dogs, pigs, chickens, and other animals, it has no brain or nervous system and is presumably quite incapable of feeling pain or anything else. It therefore can have no interests.

Why then should it have a right to life superior to that of other creatures who are so much more capable of experiencing the world? Is it because the embryo has the potential to become a full-fledged human being with a high degree of rationality and self-awareness? But if the potential of the embryo is so crucial, why do all sides agree that they would not object to disposing of the egg and the sperm *before* they have been combined? An egg and a drop of seminal fluid, viewed collectively, also have the potential to develop into a mature human being.

So if it is all right to prevent the egg and sperm from realizing their potential as a mature human being, why should it be wrong to take the same step a day or two later and prevent the embryo from realizing its potential? Until the embryo develops to the point at which it is capable of experiencing something, it is impossible to defend the view that it is a being with rights.

As a result, I don't believe there is an ethical problem with discarding a very early embryo as long as the parents give their consent. If the early embryo can be used for significant research, so much the better. What is crucial is that the embryo not be kept beyond the point where it forms a brain and a nervous system and might be capable of suffering. Two committees of leading scientists, doctors, theologians, and lay people—the Warnock committee in Britain and the Waller committee in Australia—have recommended that research on embryos be allowed, but only up to 14 days after fertilization. That is when the so-called "primitive streak"—the first indication of the development of a nervous system—begins to form.

The Warnock commitee has further recommended that it be a criminal offense to conduct research on any live human embryo derived from IVF beyond the 14-day limit. In Victoria, Australia, legislation based

on the Waller report has already passed the state parliament requiring a special review committee to approve all experimental procedures liable to harm embryos. Experimenters violating this provision can be fined or imprisoned for up to four years.

For now, such restrictions will probably not seriously hamper research. No one has yet kept an embryo alive outside the body for as long as 14 days, although Robert Edwards kept one going for 9 days. But in time the pressure to do research on older embryos will mount. And it is not obvious why such significance should be attached to the development of the "primitive streak." It would be easier to see moral significance in the formation of the elements of the nervous system that make possible some degree of consciousness or the capacity to feel pain. The parts of the brain associated with consciousness do not begin to form until approximately the sixth week, so a cutoff point for research somewhere between 14 days and six weeks may turn out to be more reasonable.

The practice of freezing human embryos with a view to later implantation is controversial mainly because of concern for the offspring. Since only a few frozen embryos have successfully been thawed, implanted into the mother's womb, and carried to term, it's too soon to evaluate the risk to children created this way. If freezing is found to carry no special risk of abnormality, its use by infertile couples would seem to be beyond reproach.

But what if the parents die without leaving instructions about the disposal of the embryos? This grim scenario has already occurred in the case of Elsa and Mario Rios, a California couple killed in a plane crash after they deposited two embryos for frozen storage in Melbourne. Neither left any instructions on disposing of the embryos, an omission complicated by the considerable estate they left to their heirs. A committee of inquiry set up by the state government of Victoria recommended that the embryos be removed from storage, a euphemism for allowing them to die. However, the state parliament disregarded this recommendation and passed a law stating that such embryos could not be destroyed. This legislation requires that these embryos be donated anonymously to an infertile couple—leaving unresolved the question of whether any resulting offspring could lay claim to the Rios' inheritance.

Surrogate motherhood raises other disturbing issues, yet it is already in use along with artificial insemination in the United States and, more recently, in Britain. In this procedure, the husband donates sperm to fertilize the egg of another woman. That woman carries the resulting embryo to term and is supposed to return the child to the original couple after birth. A growing number of clinics recruit surrogate mothers and match them with infertile couples for a substantial fee, usually at least $10,000. Any government would have difficulty stopping such an arrangement, as it does not require the services of a medical practitioner until the actual birth. Even if the procedure were outlawed, its practitioners could easily go "underground," offering surrogacy much the way black-market adoptions are offered.

Preventing Commercial Motherhood

However, we can use government regulation to try to eliminate some of the obvious problems of surrogate motherhood. For instance, we can restrict the involvement of women who are psychologically unprepared for surrogacy and may wish to keep the baby. We can make it illegal for women to abort the baby in an attempt to extract more money from the infertile couple. We can also pass legislation to prevent couples from refusing to accept the baby if it is born with a defect.

The law now regards a woman who gives birth to a baby as its legal mother. And in one landmark U.S. case, the Michigan Court of Appeals in 1981 interpreted a state law against baby "bartering" as preventing a couple from paying a surrogate mother $5,000. But the court did not decide whether being a surrogate mother without a fee is illegal.

Having surrogate mothers carry embryos produced through IVF is not so different, except that they may find it easier to part with babies that are not their genetic children. Certainly, the number of couples interested in using surrogates will increase if the offspring can be the genetic children of both parents. It would be easier to prohibit surrogacy using IVF, since this technique does require sophisticated medical services. As far as is known, surrogacy using IVF has not yet taken place. But I believe that in some cases such a procedure may benefit all parties and harm none—for instance, when a friend or relative offers to help an infertile couple. Where there is no commercial motivation, the problems are likely to be fewer.

A commercial system of surrogacy raises much

greater problems. The Warnock committee recognized this when it recommended that operating a commercial surrogacy agency, or assisting with commercial surrogacy in any way, be considered a crime. Commercializing this procedure threatens to divide our society into two groups: the poor who bear children and the rich who have others do it for them. This may bring economic benefits to the poor, but at considerable psychological cost. For now, it would seem best to restrict surrogacy to cases where the motivation is altruistic and payment is limited to the reimbursement of expenses during pregnancy.

Surrogate motherhood threatens to divide our society into the poor who bear children and the rich who have others do it for them.

A Dangerous Silence

The new reproductive technology came late to the United States because of a de facto ban, imposed in 1974, on the use of federal funds for any kind of research involving human embryos. The ban still exists today, hindering basic research in IVF and preventing federal scrutiny of applied IVF research now being conducted in private clinics throughout the United States. The ban has made it difficult for scientists, policymakers, and consumers to examine publicly the medical, ethical, and legal issues raised by IVF—a process that is now taking place in Britain and Australia. There is no U.S. equivalent to the detailed reports of the Warnock and Waller committees. These reports may not be perfect, but they are intelligent, nonsectarian contributions to the process of making public policy.

The only major U.S. document on IVF has been an ill-fated report published in 1979 by the Ethics Advisory Board of the Department of Health, Education, and Welfare, as it was then called. This report recommended that the moratorium on federal funding of human embryo research be lifted, but its recommendation has never been acted on. Politicians appear to be intimidated by the so-called "pro-life" lobby, which in this instance opposes efforts to bring about new lives where none could exist without medical intervention.

The United States urgently needs a fresh public examination of all the ethical aspects of the new reproductive technology. The challenge will be to conduct such a discussion in an atmosphere free of political threats and doctrinaire religious teachings. The President's Commission for the Study of Ethical Problems in Medicine, appointed by Jimmy Carter, succeeded admirably in probing similar problems in an unbiased, intelligent, and informal manner. However, it was dismissed by the Reagan administration before it could tackle even the most immediate issues raised by IVF.

Embryos as Spare Parts

Looking farther into the future, we can envision the application of IVF in other controversial ways. Embryos produced through IVF may someday be used to provide "spare parts" for people who, because of accident or illness, need an organ transplant. For example, embryonic tissue could possibly be used to restore nerve function in paraplegics. Embryos might be grown until organs begin to form. These organs could then be separated and grown in culture until they were large enough to be used. (Scientists can already grow embryonic mouse organs such as kidneys, lungs, pancreases, and skin in culture.) This idea has provoked howls of protest from those who regard embryos as having the same rights as normal human beings. But as long as safeguards ensure that the embryo does not suffer, it is difficult to find sound ethical objections to this proposal. And given the current shortage of donor organs, the possible benefits of this technology are considerable.

Of all the possible uses of IVF, genetic selection

and genetic engineering raise the most far-reaching questions. Should we tinker with the human genetic pool? If so, in what way?

We already tinker with the genetic pool when we offer genetic counseling, amniocentesis, and abortion to those at special risk of producing defective offspring. Genetic engineering differs from this kind of tinkering only in its techniques. But this difference is significant because the new techniques are so much more powerful. They may even allow us to select *for* desirable traits as well as *against* undesirable ones. This could be done by producing several embryos, identifying their genetic characteristics, and then implanting the most desirable embryo. Eventually, it may even be possible to modify the genetic properties of an embryo before implantation to eliminate defects and build in desirable qualities.

Many people fear that governments will use the new genetic techniques to design future generations to be docile.

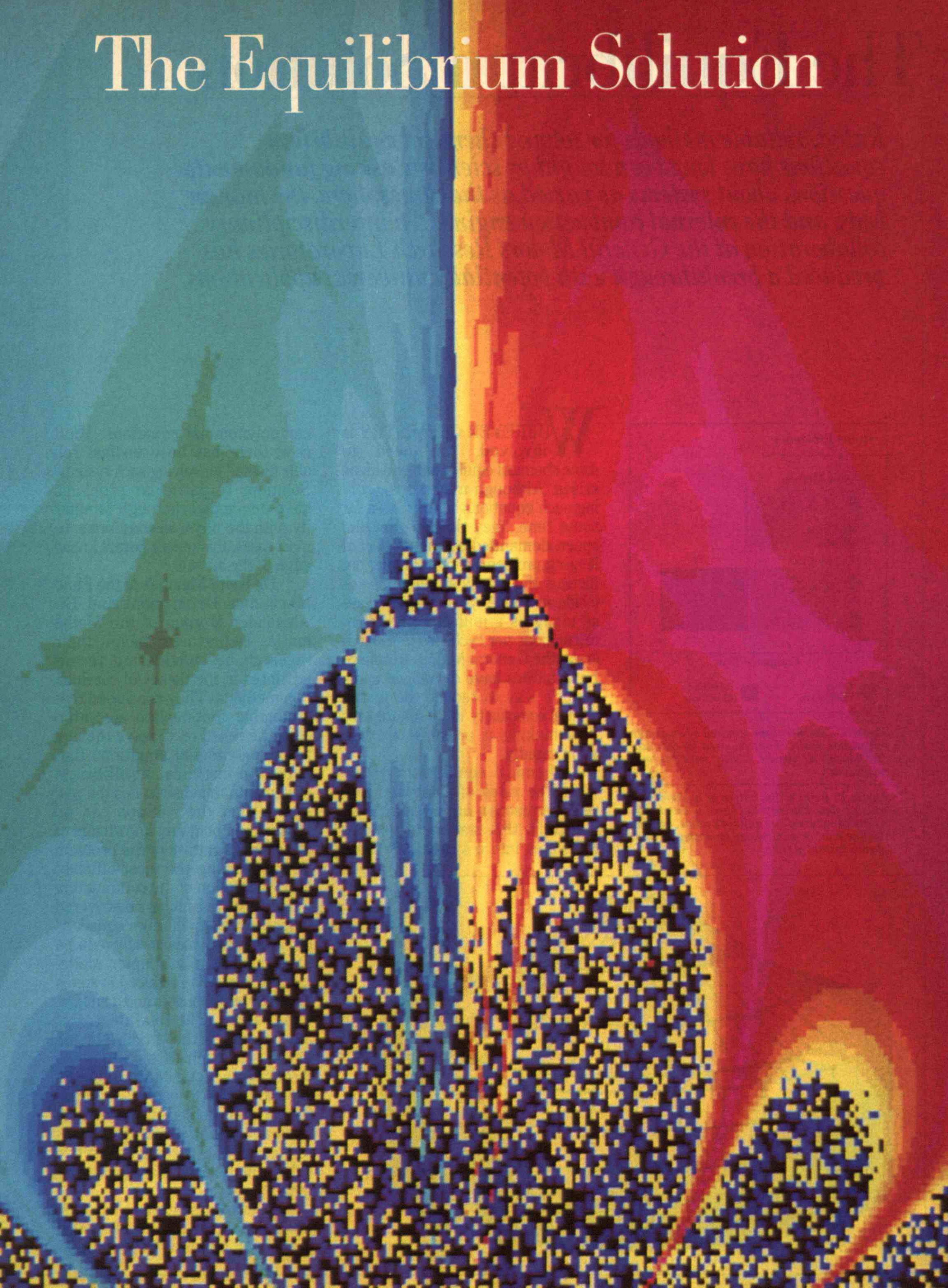
In the next few months, physicians in the United States may attempt to perform gene therapy on children who suffer from Lesch-Nyhan syndrome, a devastating brain disorder that leaves children profoundly retarded; the syndrome is caused by the lack of a single normal gene. The treatment—the first approved human trial in the United States—would involve inserting the needed gene into bone-marrow cells taken from the patient. The genetically engineered cells would then be injected back into the patient's body, presumably to multiply and provide enough of the normal gene. Gene therapy may also be used to eradicate other genetic diseases in the womb. Eventually it could be used to eliminate relatively minor defects in the body and perhaps even the mind.

In time, we may even decide to build in positive modifications. After all, natural selection has left ample room for improving the human race. And the ethical line between eliminating defects and making positive modifications is difficult to draw. If we learn how to affect intelligence, should we stop short at eliminating mental deficiency? If we eliminate abnormally depressive personalities, would it be wrong to try to produce people who tend to be a little more cheerful than most of us are now? If we eliminate tendencies toward criminal violence, might we not build just a little more kindness into the human constitution?

Many people are concerned that these techniques would be abused. Some fear that they would place too much power in the hands of governments, who will not be able to resist the temptation to design future generations to be docile. But I believe these fears are exaggerated. If we have succeeded in keeping our freedom in the age of television, snooping devices, and computers, we should be able to cling to it when we have the means to manipulate genetic traits as well. The technical ability to suppress liberty has been with us for a long time. It is our determination to prevent our rulers from exercising this ability that has kept us free. We can continue to do so, even in the age of genetic engineering.

PETER SINGER is professor of philosophy and director of the Center for Human Bioethics at Monash University, Melbourne, Australia. He is co-author of The Reproductive Revolution *(Oxford University Press, 1984; Scribner's, forthcoming).*

The Equilibrium Solution



The Equilibrium Solution

Rapid, reliable methods for solving chemical equilibrium equations have long been sought by scientists asking fundamental questions about systems as varied as the atmosphere, the human body, and the internal combustion engine. An interdisciplinary collaboration at the General Motors Research Laboratories has produced a breakthrough with potentially universal applications.

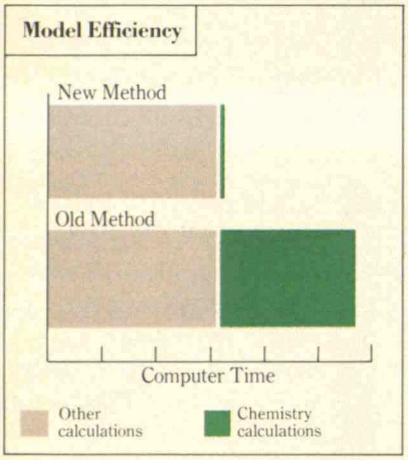
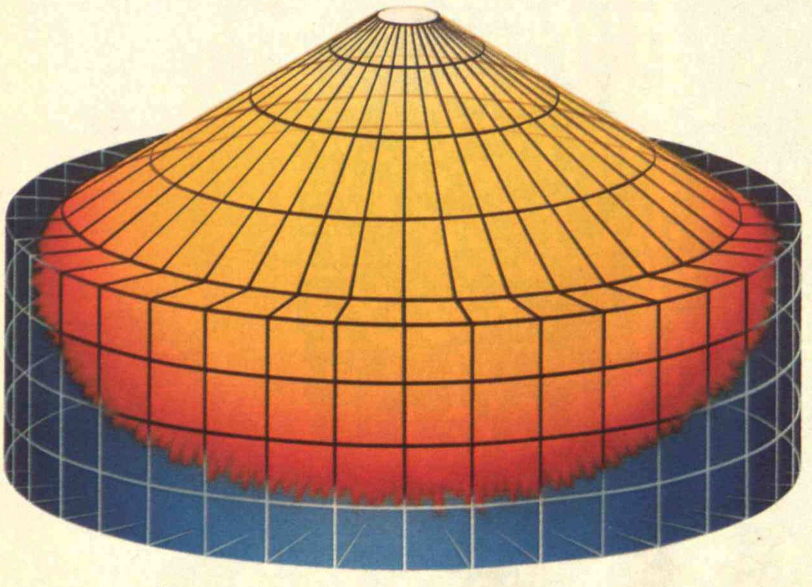


Figure 1: Computer time required by an engine combustion model. Time required for chemical calculations decreased greatly with the new methodology.

Figure 2: Artist's illustration of a chemically reacting flow. The physical space is divided by a latticed network into units of volume, and the solution must be recalculated for each grid point at each instant of time.



WHEREVER CHEMISTRY is involved, the need to solve chemical equilibrium equations arises. Although methods for solving such equations have existed for some time, they do not offer the speed demanded by the most challenging problems. For example, predicting the composition of gases inside an engine cylinder may require as many as a million equilibrium calculations per cycle. Two researchers at the General Motors Research Laboratories have developed a systematic way to reduce the mathematical complexity in these problems, thus making it possible to solve them rapidly.

Chemical equilibrium occurs when the rates of a forward and reverse reaction are equal. Mathematically, this statement usually translates into a system of nonlinear polynominal equations. Until now, there has been no fast reliable method for solving such systems. Solutions to particular problems have demanded thorough familiarity with the physical conditions. In most cases, this means partial knowledge of the answer.

Dr. Keith Meintjes of the Fluid Mechanics Department and Dr. Alexander Morgan of the Mathematics Department began their research by considering recent advances in the theory of continuation methods. They concluded that a suitable continuation algorithm could be relied on to solve the nonlinear polynomial equations that make up chemical equilibrium systems. In this insight lies the realization that the solution can be obtained without any knowledge of the physical nature of the problem.

In seeking the most efficient implementation of the continuation method, the researchers discovered that chemical equilibrium equations can always be systematically reduced to a substantially simpler mathematical form. The reduced systems have fewer unknowns and a smaller total degree. The total degree of any system is the product of the degrees of each of its equations. Reducing the total degree makes a system easier to solve. A typical combustion problem with ten equations and total degree of 192 was reduced by the researchers to two cubic equations with a total degree of nine.

The reduced systems can then be systematically scaled to fit within the limits imposed by computer

arithmetic. The range of coefficients in chemical equilibrium systems tends to be too large or too small for the arithmetic of the computer. Consequently, the solution process can fail. By construction of an effective scaling algorithm, this arithmetic constraint can be eliminated. Suitably reduced and scaled, the equilibrium systems can then be solved reliably by the continuation method.

THUS, Drs. Meintjes and Morgan accomplished their original goal of developing an innovative reliable approach to solving chemical equilibrium equations. They also made a final, unexpected discovery. Certain standard solution techniques, which fail on the original systems, can be made absolutely reliable when applied to the reduced and scaled systems. These methods, which are variants of Newton's method, are also many times faster than continuation.

This research has produced an extremely effective solution strategy—reduction of the equations, followed by scaling of the reduced systems, followed by the application of a suitable variant of Newton's method. The simplification of the systems, which was originally formulated to facilitate the implementation of the continuation method, proved to be the critical factor enabling the use of fast techniques.

In one application, the chemical equilibrium calculations are part of a model which predicts details of the flow, turbulence, and combustion processes inside an engine. By using their methodology to develop an equilibrium solver for this application, the researchers greatly increased the model's solution efficiency (see Figure 1).

"It was the characteristic structure of equilibrium equations," says Dr. Meintjes, "that allowed us to perform the reduction. The unexpected mathematical simplicity of the reduced systems suggests that even more efficient solution methods may be discovered."

"Critical to this research," says Dr. Morgan, "was the dialogue between disciplines. I hope that this dialogue will continue as scientists and engineers in diverse fields explore the capabilities of this new methodology."

THE MEN BEHIND THE WORK

Dr. Keith Meintjes, a Staff Research Engineer in the Fluid Mechanics Department, joined the General Motors Research Laboratories in 1980. Dr. Alexander Morgan, a Staff Research Scientist in the Mathematics Department, joined the Corporation in 1978.

Dr. Meintjes (left) was born in South Africa. He attended the University of Witwatersand, where he received a B.Sc. and M.Sc. From 1973 to 1975, he taught fluid mechanics and engineering design at the university. He then went on to study at Princeton University, where he received an M.A. and Ph.D. in engineering. His doctoral thesis concerned numerical methods for calculating compressible gas flow.

Dr. Morgan (right) received his graduate degrees from Yale University in differential topology. His Ph.D. thesis concerned the geometry of differential manifolds. Prior to joining General Motors, he taught mathematics at the University of Miami. His book, "Applications of the Continuation Method to Scientific and Engineering Problems," will soon be published by Prentice-Hall.

Computers are learning how to carry on a normal conversation by capturing the richness of dialogue, gestures, and glances. The interface between people and computers will be much friendlier as a result.

Conversing with Computers

BY RICHARD A. BOLT

WHEN I see an advertisement heralding a certain computer or program as "conversational," I just don't believe it. To me, conversation is speaking back and forth, pointing out this or that—a lively dialogue that involves glancing about and following the other person's glances as well as using gestures to describe, indicate, and emphasize. Whether the topic is trivial or weighty, conversation means a strong sense of another's presence in a setting we both share.

If you have used a computer at all lately, you know why I'm skeptical about claims that they are "conversational" in this rich sense. Yet I believe that such a relationship between people and computers will come about, and in fact I have been trying to help make it happen. For the past eight years I have been working in M.I.T.'s Architecture Machine Group laboratory, founded in 1968 on the basis of Nicholas Negroponte's optimism about the future of human-machine communication. My role is to combine a background in computers with insights from cognitive psychology to improve the interface where people and computers meet.

The rationale for making computers truly conversational is, to borrow a phrase from Professor Negroponte, to provide "supreme usability." This means making the computer as easy and as interesting to talk to as another person, for the novice or occasional user as well as the computer veteran. Despite vaunted claims of "user friendliness," even today's most advanced computer systems—in industry, homes, or the military—are too often excruciatingly difficult and frustrating to use. Of course, many research groups are actively following a variety of paths to make computers friendlier. But at the risk of seeming immodest, what sets our laboratory apart is the zest with which we are bringing many disciplines to bear on the problem.

Our goal is not simply a utilitarian one of enabling a manufacturer, for example, to produce so many more widgets per unit of time. Rather, we

PHOTOGRAPH: WALTER BENDER AND RICHARD BOLT

Somewhere along the way we've lost the expectation that interacting with computers can be as natural as carrying on a conversation.

want to enhance the quality of the human-computer interface in its own right. We are convinced that using a computer should be a pleasurable, even exhilarating, experience. Whatever else computers are, they should be fun.

This is in many ways a radical idea. Many people have long since adopted the notion that computers are for "getting the job done." They can be improved, certainly, but they will basically remain tools that you put up with for the sake of the task at hand. Somewhere along the way we've lost the expectation that interacting with computers can be as natural as . . . carrying on a conversation. We've been forced, largely by commercial vendors, to be thankful for small advances toward user friendliness. But our group believes we shouldn't mistake microsteps for real progress. Our sights are set on the root meaning of "to converse": to *keep company with*. It is this conviviality that is now so egregiously absent from our experience with computers yet so vital to our sense of ourselves.

Put-That-There

Personal computers are now on the market that let you point at items on display, either by putting your finger on a touch-sensitive screen or by manipulating a "mouse," a small device on a cord that controls a cursor on the display screen. There are computers that let you speak to them, comparing your message with stored samples of your speech. Some such recognizers handle only discrete speech—that is, phrases spoken one word at a time. Others can handle normal speech in which words are strung together with no pauses in between.

But computers that let you use both gesture and speech are not yet offered by commercial vendors. The expressive power of speech and gesture combined clearly exceeds that of either alone—hence the importance of using both to communicate with computers. We have made a start toward this goal.

For example, several years ago I originated an exercise called "Put-That-There." The setting for Put-That-There is a special room that becomes a computer terminal you enter rather than sit at. Called the Media Room, it is about the size of a personal office: eight feet high, ten feet wide, and roughly thirteen feet long. The front wall is entirely display screen on which images can be created by a projector located behind the screen (*see page 39*).

The user sits at the center of the room wearing a microphone wired to an automatic speech recognizer. The recognizer is of the "connected-speech" type and has a vocabulary of 120 words. The user also wears a wristwatch band to which a small plastic cube is attached. This cube works in concert with a similar but larger cube mounted on a pedestal close to the chair. Both cubes generate magnetic fields when activated. From the relative position of the two magnetic fields, an associated computer calculates the position and orientation in space of the smaller cube, making it effectively a wrist-borne "pointer."

In Put-That-There, you create objects on the display screen simply by talking and pointing. You can name them, change their color and shape, move them about, and delete them. For example, you might say, "Create a large green circle . . . there"—while pointing with your raised arm at some spot on the screen. The system responds by putting up a large green circle at the spot you indicated. Next you might change the color of the circle by pointing at it and saying, "Make that red."

Instead of manipulating simple shapes on a plain background, you might manage color-coded ships against a map of the Caribbean. You can say, "Put a large blue tanker (pointing) there." Or "create a yellow freighter southeast of Haiti." Then you name the ship: "Call that (pointing to the freighter) the *Flying Cloud*."

The information you give by either hand movements or speech need not be perfect. Put-That-There requires only that gestures and speech, when considered together, converge upon what the user intended. Suppose you point to some spot on the map and issue the command, "Put the green freighter there"—but you mumble a bit on the phrase "green freighter," so the match with the prerecorded phrase is only marginal. A speech recognizer would ordinarily declare it a miss. Your pointing, too, is a bit wobbly, hitting the freighter but sweeping by some other ship's image as well. In other words, the data taken separately from either mode are ambiguous. Combined, though, the evidence gains strength. "Green freighter" is a plausible interpretation of what you intended to say, as you did in fact point toward the freighter, though you hit other items as well. The system, able to weigh the evidence from both modes, draws the reasonable conclusion that you probably did intend to move the green freighter.

This ability to use pronouns and adverbs instead

of names and descriptions—and to point at the objects—reduces the usual problems of automatic speech recognition. It's like being able to identify one clown out of a crowd of them, not by saying "the tall clown with the purple nose and the green jacket," but by pointing and exclaiming "him!"

Vendors of automatic speech recognizers typically claim that their products are at least 99 percent accurate. But such levels of accuracy are achieved only under optimal testing conditions, including low noise levels, trained speakers, and specially selected vocabularies. Performance under more realistic conditions may reach only about 65 percent. Obviously what matters is the *effective* level of communication—not the narrow issue of speech recognition but the broader and more fruitful one of speech interpretation.

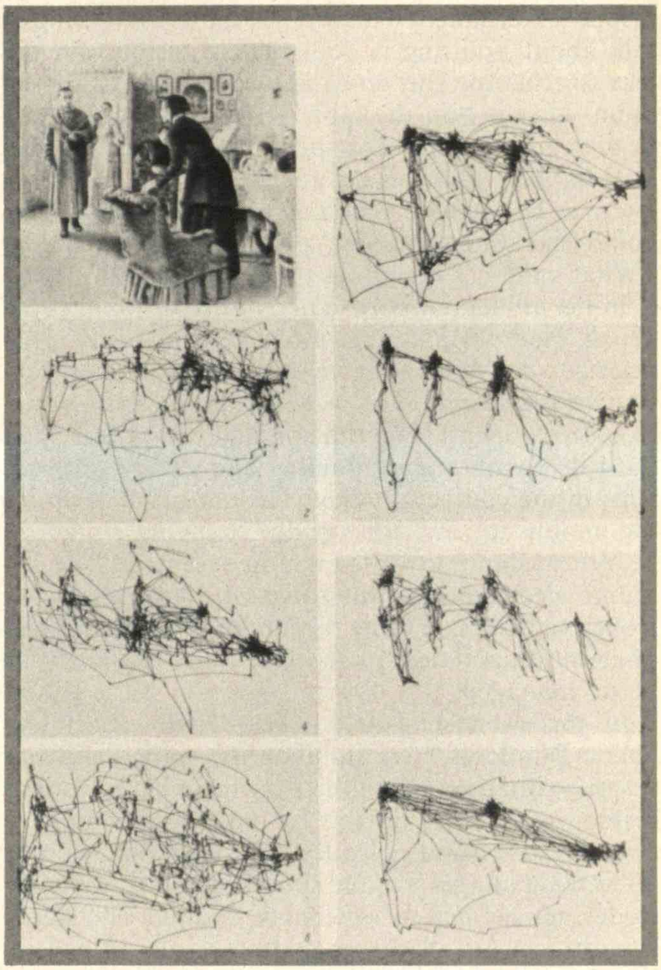
The Put-That-There system takes the situation into account when interpreting speech. Suppose you say, "Create a blue freighter there," and the speech recognizer misses the command "create." On the basis of syntax alone, the missing word could be "create" or it could be "move." The system resolves that uncertainty by knowing whether a blue freighter already exists. If one doesn't, the system properly infers that the missed word must be a create command, not a move command, and so it puts a blue freighter at the indicated spot.

Chris Schmandt and Eric Hulteen, who programmed Put-That-There, did their utmost to avoid making the user repeat words unnecessarily. Suppose the user says, "Move *Flying Cloud* northwest of Haiti." If the word "northwest" is missed, the system simply asks, in its synthesized voice, "What direction?" It does not demand that the entire command be repeated. Computer visionary Alan Kay, in an interview in *Psychology Today*, characterized interacting with the Put-That-There system as being "like dealing with a friendly, slightly deaf butler. . . . From the standpoint of your expectations, you are willing to deal with it." Indeed, our aim is to make the user feel that despite inevitable lapses in word recognition, the system is doing its best to understand the user's intent. Achieving such user confidence is a big factor in any system's acceptance.

Telling Glances

Developmental psychologists tell us that one of the first things a child learns is to follow the mother's line of gaze as she speaks about things. For example, the child hears the sound "kitty" while following the mother's gaze to that lively, furry creature. Similarly, we can tell where someone's visual attention is directed by watching the eyes. By contrast, we cannot directly determine "where" a person is listening; people's ears don't angle about like a rabbit's do. But interestingly enough, psychologists have found evidence for a link between eye position and auditory attention: we tend to listen in the direction we are looking.

A computer can determine a user's interests by tracking eye movement. In his classic studies, Alfred Yarbus asked people to examine repeatedly a painting (upper left). Before each trial, he gave the observer a question to answer afterward. Here, the observer's "looking patterns" differed markedly with each question. (From *Eye Movements and Vision,* Alfred Yarbus, 1967. Used with permission of Plenum Publishing Corp.)



This conversational strategy of watching where the other person is looking—as a way of tapping into what that person is paying attention to—can help a computer. By monitoring which part of the display screen the user is looking at, the machine can better understand what the user is interested in and is trying to communicate.

In a complementary sense, the computer's graphic

I envision a "self-disclosing" computer system that need not tell you how to operate it or what services it can provide.

display externalizes what the computer is offering to talk about—putting it "out there," visibly, for the user to react to. This tends to focus the user's speech upon what is "on the table" for discussion, which in turn greatly simplifies speech recognition by putting implicit limits upon the range of vocabulary likely to be used. At the same time, the display provokes the user's looking, pointing, and speaking: "What's this? Where does that come from?"

In his influential book *The Nature of Managerial Work*, Henry Mintzberg of McGill University characterizes the managerial world of the modern executive as one of brevity, variety, and fragmentation. Executives spend little time on any one activity and must deal with a great number and variety of problems in the course of a day. They must be in up-to-the-minute touch with rapidly changing situations yet not succumb to "information overload." We can mimic electronically this salvo of events that confront executives—events demanding various degrees of attention and decision—to see how they might be better managed.

In the exercise called "Gaze-Orchestrated Dynamic Windows," we simulate the spirit of such a volatile situation in graphics on the Media Room's display screen. We do this by creating a composite of many television episodes—a collection of up to 40 moving images playing simultaneously. Some episodes appear just as others are ending. The stereo soundtracks of all the episodes are also piped in, creating a kind of "cocktail party" mélange of voices and sounds. We then exploit the selective visual attention of our hypothetical manager to orchestrate this complex, dynamic display—that is, we let the user's eyes help sort out what he or she wants.

The user sitting in the Media Room wears glasses that have a miniature eye-tracking system mounted in the frame. The device, developed by the Denver Research Institute, shines a tiny beam of infrared light onto the cornea and traces the reflection. This provides a constant measure of the position of the wearer's eye with respect to the glasses. We also mount on the frame a small location-sensing cube—the same kind worn on the wrist in Put-That-There—to detect the position of the frame within the room. The measurements of eye position in the glasses and frame position in the room combine to reveal where the user is looking on the display screen.

Whenever the system finds that the user is looking steadily at a particular image, it turns off the soundtracks of all other episodes. If the user persists in looking at this episode for a few seconds or so, the system "zooms in" to fill the screen with that image. To recover the many deleted images, the user simply moves a joystick mounted on the arm of the chair. The net effect is to allow users to filter out all but the information of immediate interest, while enabling them to return at will to the more complex environment. We think this offers a way to exploit people's natural processes of selective visual attention to help them focus on the most relevant events in the midst of near-overwhelming complexity.

Computers as Good Hosts

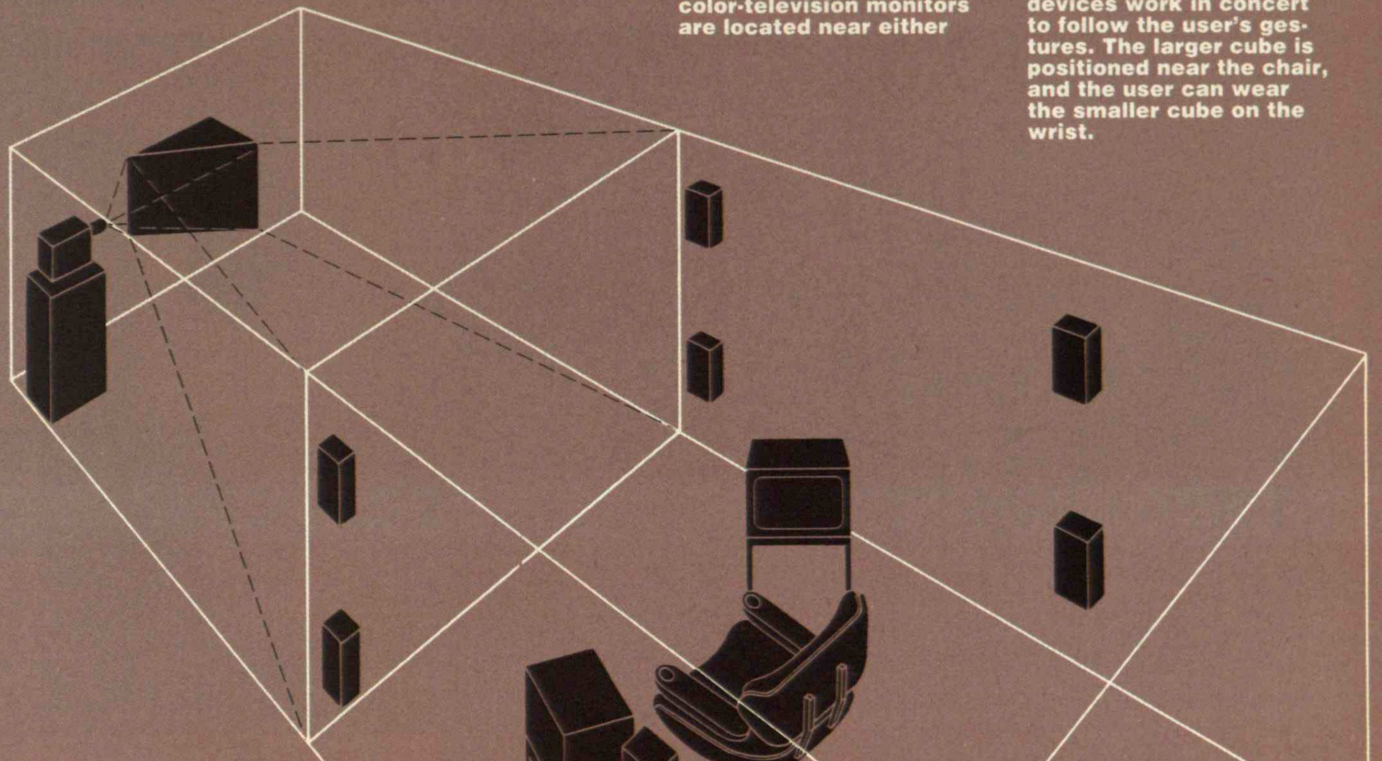
Computers that know where on a display the user is looking and can capture speech and gesture suggest the possibility of "self-disclosing" systems: computers that tell about themselves. I don't mean simply that the computer would be "manual-free," although that would be a blessing unto itself. The reams of printed material that accompany some personal computers sometimes seem to weigh more—both physically and intellectually—than the hardware. Rather, I envision a self-disclosing system that need not tell you how to operate it at all or what services it can provide.

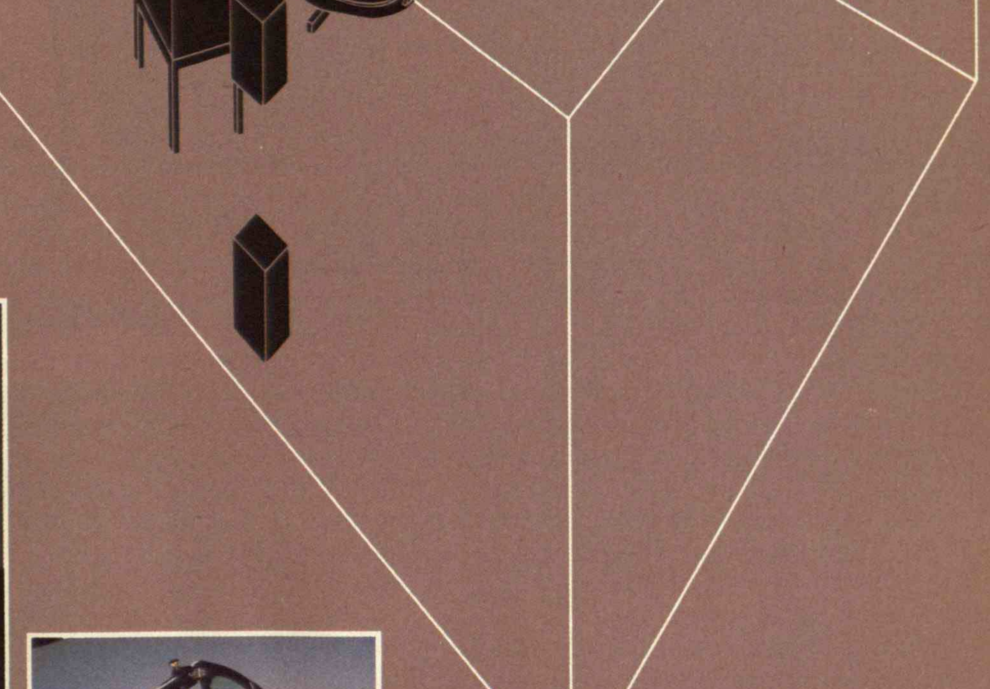
This computer would be instrumented to respond to your presence and normal behavior. It would have a full-color graphics display and eye-tracking capability for determining where on its display you are looking. You would be able to point at it and speak to it, and the computer would communicate back with synthesized or recorded speech as well as text on its display. It would disclose its contents—its information base—according to the interests you exhibit through your actions, and would do so at a speed that matches your own.

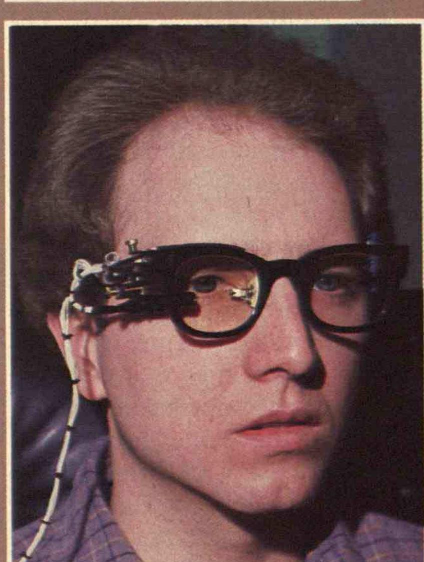
This system would interact with its user just as one person would interact with another. Suppose you breed guinea pigs and are showing someone the badges and ribbons your cavies have won, which are displayed in your trophy room. As a good host you try not to dominate things but remain alert to the cues your guest gives off: what is he looking at, what does he say, what message is his "body language" sending? Suppose the guest, surveying a wall full of ribbons, asks, "What are those?" You respond: "Those are the ones we won over the years at the Westfield Fair and Exposition." A certain trophy

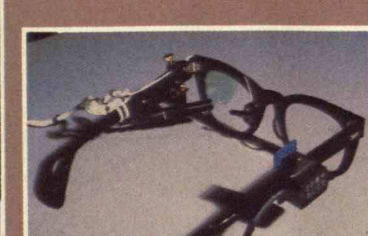
The Media Room at M.I.T.'s Architecture Machine Group laboratory serves as a computer terminal that you enter (see diagram). The user sits facing a large display screen on which images are projected from behind. Touch-sensitive color-television monitors are located near either arm of the chair, and eight speakers provide "wraparound" sound.

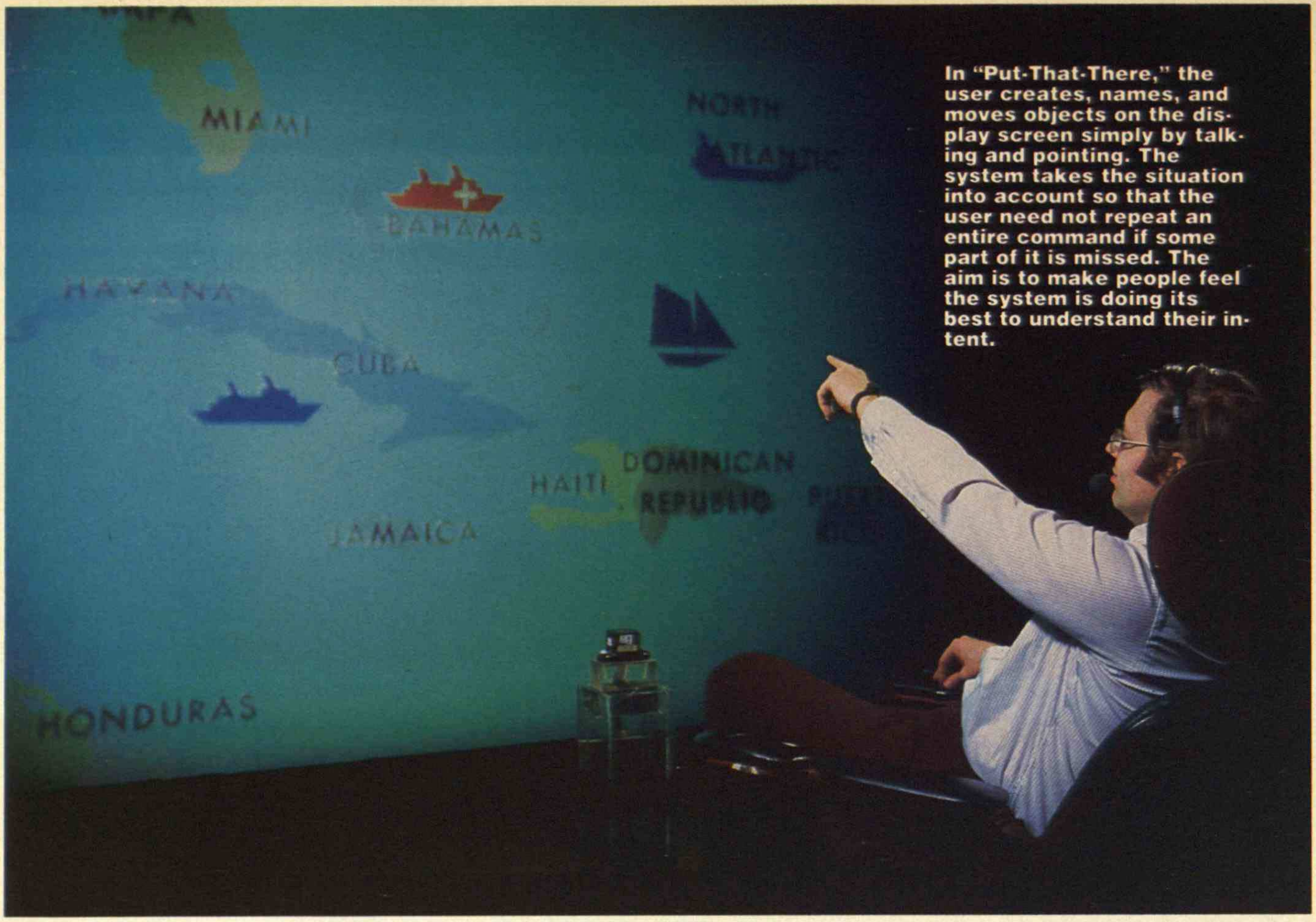
In some exercises, the user wears glasses equipped with an eye-tracking device that monitors where on the screen he is looking (lower left). Two "position-sensing" devices work in concert to follow the user's gestures. The larger cube is positioned near the chair, and the user can wear the smaller cube on the wrist.











In "Put-That-There," the user creates, names, and moves objects on the display screen simply by talking and pointing. The system takes the situation into account so that the user need not repeat an entire command if some part of it is missed. The aim is to make people feel the system is doing its best to understand their intent.

catches your guest's eye. You take it from the shelf and offer it for closer inspection. Your guest reads the inscription and inspects the detail. Then his eyes turn elsewhere, a cue for you to relieve him of the trophy and go on to something else. Next your guest's eyes range over a set of distinctive badges. "What are those?" he asks—the very question he uttered a moment before. But it has become a *different* question, changed by the direction in which he is looking.

Consider now that our self-disclosing computer is showing such a collection of items. The computer's display sets the topic, just as did the real-life artifacts of the trophy room. The computer—like the human—can determine where its guest is looking, listen to his speech, detect his gestures. The system can then zoom in upon the item or area of interest to discuss it.

Such a computer can act very skillfully in deciding what and how much to tell about the subject at hand, again by taking its cues from the user's eyes. There is evidence that the eyes reveal the pattern of an observer's curiosity along very specific lines. In his classic eye-tracking studies in the Soviet Union during the 1960s, Alfred Yarbus asked people to examine a copy of the famous nineteenth-century painting by Ilya Repin entitled "They Did Not Expect Him." The scene is of a young man just returned from political exile to the midst of his startled family. Before looking at the picture for three minutes, each observer was asked one of a number of questions: What are the ages of the people? What are the material circumstances of the family? What was the family doing before the young man arrived? The observers' "looking patterns" differed markedly depending upon their goals as set by the question.

Of course, the computer must be able to tell the difference between a protracted stare stemming from the fact that the viewer is puzzled by something and blank staring stemming from saturation. But that is not likely to be difficult: researchers studying eye movements have found that eye patterns when interest is saturated differ from those when curiosity is live. Furthermore, pupil diameter varies with tension, interest, and suspense. These cues, coupled with what viewers say, can help a machine make reasonable inferences about when to move on. The machine can also gauge the effectiveness of its presentation by checking whether viewers look in the right places when it tells them about a display. If viewers fail to look at a relevant spot, the computer can reemphasize or recast its explanation.

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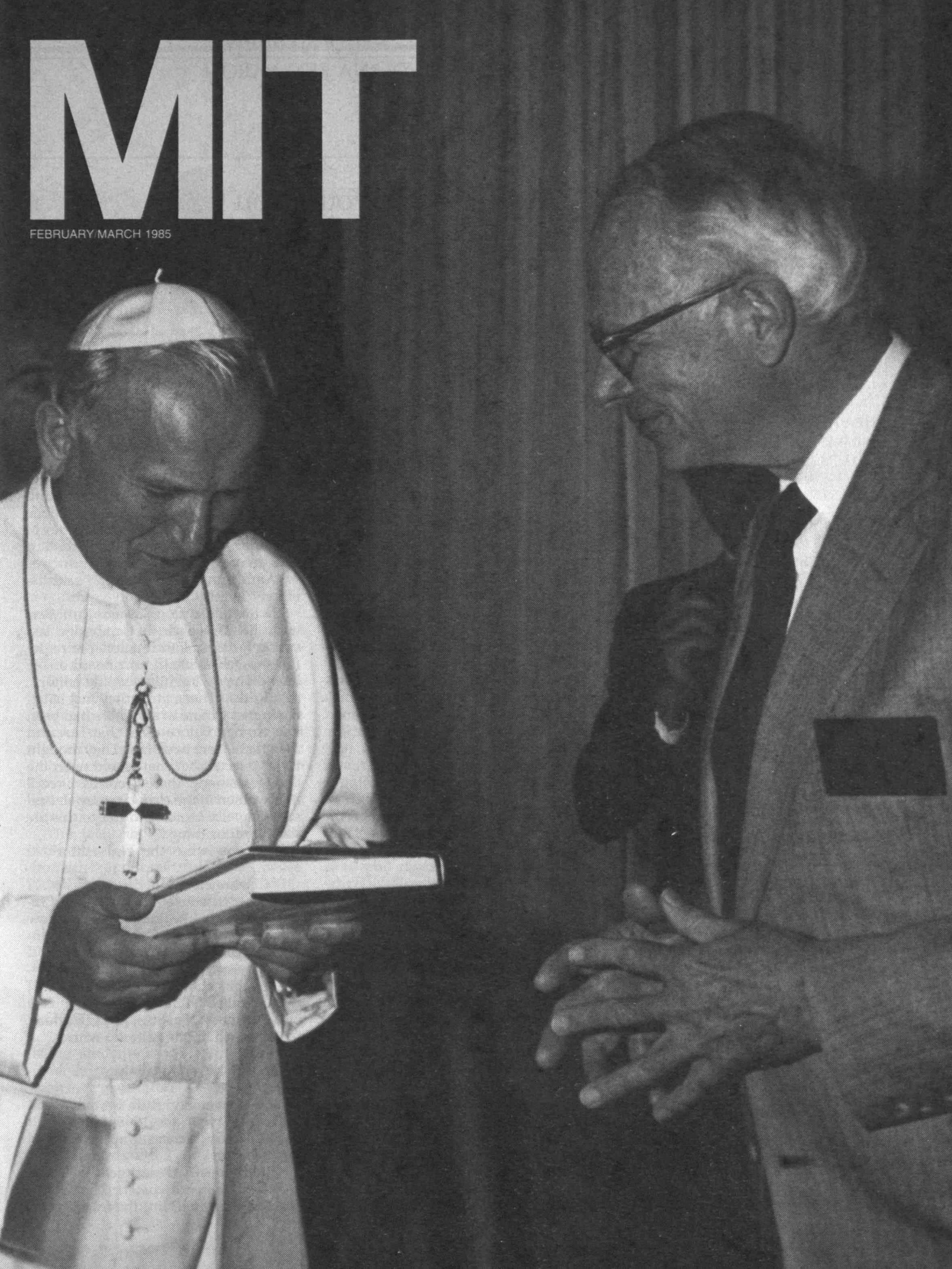

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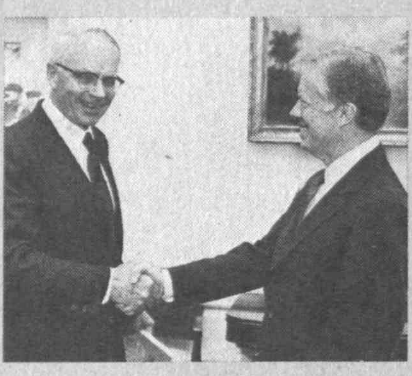


ABOUT THE COVER

Technical studies are not usually unveiled at the Vatican. But when Carroll Wilson, '32, was developing a global audience for the 1980 report of the World Coal Study, a book entitled Coal—Bridge to the Future, ***he presented copies to both Pope John Paul and President Carter. It was typical of Wilson to both value and have access to the support of world figures for the seminal ideas he championed. Cover photo courtesy of*** L'Osservatore Romano; ***above, Official White House Photograph; story, p. A4.***

STUDENT VIEW

DIANA BEN-AARON

Would You Send Your Daughter To M.I.T.?

"Would you send your daughter to M.I.T.?" That's still a slightly different question from the traditional "knowing what you know now about the pace and pressure (read: 'meat grinder') of the Institute, would you send your child there?" For one thing, M.I.T.'s stereotype and population are overwhelmingly male; women at M.I.T. are just a little bit hard for many people to imagine.

For another, many parents are more protective of their female children. What other explanation could there be for the number of women who live in McCormick Hall, M.I.T.'s all-women dormitory? Would their parents let them stay at M.I.T. if they chose a coed dorm or independent living group instead of McCormick, where the doors of the building are locked at 1 a.m., and residents are not issued keys?

Finally, an historically male atmosphere that is still predominantly male implies discrimination against women. Doesn't it?

"Most of the discrimination I have heard of is directed at the support staff and graduate students, not the undergraduates," Mary Frances Wagley, '47, president of the Alumni Association and member of the M.I.T. Corporation, said last summer. "And I think the junior faculty have a pretty tough time of it. But what I hear from the undergraduates is, don't make a special case of our being women, just let us be students and do our work."

So, How Do You Like Wellesley?

I had to agree. Although there is still an occasional professor who asks if you like it at Wellesley, or male colleague who judges every woman he sees on her physical appeal to him, the overall atmosphere is usually one of cooperation and equality. Women who do very well academically are not "exceptions," while those who have difficulty are not dismissed as "proof that women are no good at science." If I had a daughter who was at all interested in obtaining a scientific grounding in a friendly environment, I would encourage her to apply to M.I.T.

The atmosphere for undergraduate women has not always been this supportive. One afternoon just before Commencement last June, two women walked into the office of *The Tech*. They came into the room in much the way I imagine Katharine Graham walks into the *Washington Post*.

"I want a retraction," said the taller one. "You printed on the 100th anniversary of the newspaper that someone else had been the first woman editor of *The Tech*. I was the first woman editor of *The Tech*.

"And I was features editor," said the other. "In 1939."

Ida Rovno Gordon, '39 and Ruth Berman Pitt '39—back in Cambridge last spring for their 45th reunion—were the first women elected to the board of *The Tech*. "They wouldn't elect Ida editor," said Ruth. "Those men, they just hated having us around at all. There had been one women before us at *The Tech* and then there were two of us. They thought if they elected her that would open the floodgates—and there were as I recall four women in the class. So they elected someone else editor and Ida to this assistant editor thing."

"But you were the real editor?" I asked.

Both women nodded vigorously. "I wrote outrageous editorials," Ida recalled. "Often the editor didn't know what they meant. The rest of the managing board was very conservative. I wrote one on the sex life of M.I.T. men—the double standard. [Dean Harold] Lobdell called all the men from *The Tech* on the carpet—of course, he didn't think the girls had anything to do with it."

Chemistry Most Hospitable

Like Ida Rovno and Ruth Berman—and the plurality of pre-1960s women at M.I.T.—Mary Frances Wagley majored in chemistry.

"The chemistry department then was very hospitable to women. The professors were all men, but they were good

and kind and fair. I had been a chemical engineer, but they talked me out of that. There was a chemical engineering summer camp, and I did not want to be the only woman at a boys' summer camp. . . . Also, one of my apartment-mates was in chemistry too. She was several years ahead of me, but it made it easier."

The same widening of options that is now distributing women more evenly among the departments is causing more women to apply in the first place—but the number is nowhere near 50 percent. "So many women out there don't even consider M.I.T.; . . . they often underestimate themselves," laments assistant director of admissions Marilee Jones.

The fact that proportionately more women than men are admitted to M.I.T. from the applicant pool sparks occasional insinuations from men either rejected or present that someone is (or all women are) admitted because of gender. The remark is usually accompanied by a quotation of the admission statistics for good quantitative measure.

In fact, says Brenda Hambleton, '79, assistant director of admissions, a woman applicant has a better chance of getting in because she is likely to be a better student. It still takes more *chutzpah* for a woman to apply to M.I.T. than for a man. Admissions office efforts to encourage more women to apply to M.I.T. and more admitted women to attend—neither of which lowers or alters the standards of the admissions process itself—have increased the percentage of women from 20 percent to 25 percent over the last six years. This year's freshman class has 28.6 percent women, 308 out of 1076 students. And if any of those women feels outnumbered or different, she should consider what it's like at some other technical schools. In Cal Tech's freshman class of almost 206, there are 26 women.

Housing Not a Trivial Issue

I tend to feel insulted by any kind of special treatment for women at M.I.T. For instance, I used to feel enraged about the existence of the Margaret Cheney Room for women. Why did we need it? Didn't M.I.T. think we could make it alone? It took me a long time to realize that the early women students, the ones who paved the way for the rest of us, probably couldn't have. Until 1963, when McCormick Hall was built, all women had to live off-campus, at great inconvenience. Today, the Cheney Room is used principally by graduate students, who have more need of a campus refuge. They are more vulnerable to sexual harassment because they are fewer and must work so closely with their professors, and many of them must still live off-campus because of the shortage of graduate housing.

"The housing system was very unfair when I was at M.I.T.," said Wagley. "Three of us lived in an apartment in Boston and after a three-hour lab we would have to go all the way back, go to a grocery store and cook dinner. We took turns, but it was very difficult, when we had all this homework to do."

"I lived in Brookline, and then in Central Square, and then across the river," said Ida Rovno. "Of course, it is much better now," she added. Her daughter was among the first residents of McCormick Hall.

Do you know what looks like the most difficult thing I'll have to do, asked Wagley when she began her term as president? "I have just been talking to the last president of the Alumni Association, Bob Mann," she said, "about the gold mace the president of the Alumni Association carries at Commencement." I had seen the 2-foot-high gold staff, engraved with gears and atomic orbitals and surmounted by a beaver. It is something that Mann, at 6'1" is better equipped to handle than his 5'4" successor.

"The president has to carry it from 77 Massachusetts Avenue to the front of the court. You can carry it over your shoulder like a pair of skis. Then you have to hold it up next to you (on an oversized golf tee) until everyone is seated. Dr. Mann said he could hardly hold it up through the 45 minutes of the procession and I had better get Buildings and Grounds to rig up a prop for me.

"I think that will be my biggest problem," said Wagley.

I think so too. □

DIANA BEN-AARON, '85, IS EDITOR-IN-CHIEF OF THE TECH. *SHE IS A HUMANITIES AND MATERIALS SCIENCE MAJOR.*

ILLUSTRATION: ELIZABETH SLOTE

Activist on the World Stage: Carroll Wilson Remembered

When the late Carroll Wilson, '32, was 14 years old, his parents sent him to a respected prep school. Finding that the boys were preoccupied with sports and other "rotten" stuff, Wilson sent two or three registered letters *per day* to his parents threatening to walk home to Rochester, N.Y., if they did not come to retrieve him. They did. And that may have been the last time anyone succeeded in forcing Carroll Wilson to be distracted by things he didn't want to do.

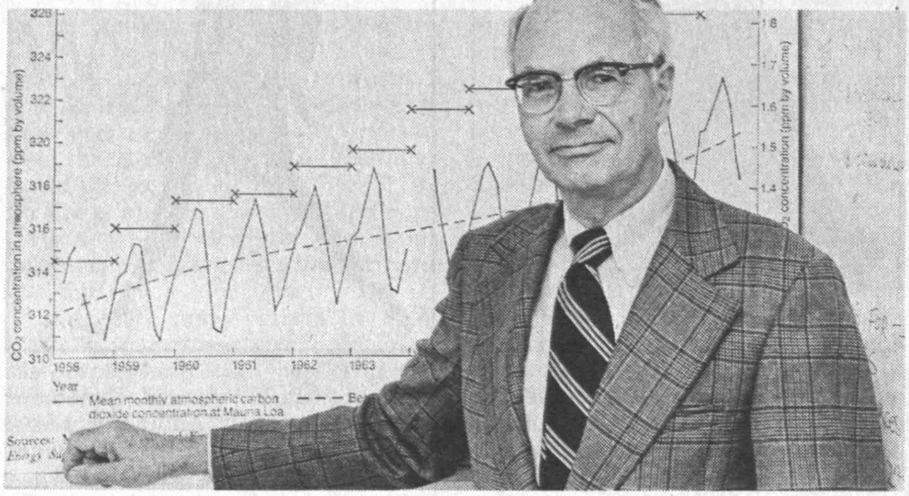
That anecdote will sound perfectly in character to the 40 or more of his former colleagues who will assemble in Cambridge on February 2 to mark the second anniversary of Wilson's death. Although single-mindedness was a quality they admired in Wilson, his spiritual heirs will be gathering primarily to preserve Wilson's legacy of action on a global stage, his concern for the major problems of humanity, and his faith in the leadership ability of the young.

Their annual gatherings are the most visible part of an effort to raise $250,000 to support a permanent series of Carroll Wilson Awards. Constantine Simonides, '57, says the awards are expected to provide $3,000 to $10,000 annually to several individuals who present imaginative plans for international travel, study, and research.

Howard Johnson, a friend as well as colleague of Wilson, would like to see the awards go to young people whose proposals reflect a willingness to launch themselves "from a standing start" into a totally new intellectual frame of reference—a mode of action absolutely typical of Wilson.

Linchpin for *The Limits to Growth.*

Wilson, whose varied career included being the first general manager of the Atomic Energy Commission (AEC), joined the faculty of the Sloan School in 1959. For more than 20 years he used M.I.T. as a base while demonstrating his skills as an initiator of meetings (both national and international), a link among policy-makers, an assembler of information, and a molder of world opinion on major issues such as energy supply, global climate change, and alternatives to nuclear arms.



After his 1971 Stockholm study of human impact on climate, Carroll L. Wilson, '32, displays for the press a chart of rising CO_2 concentrations in the air at Mauna Loa, Hawaii.

Never a traditional classroom teacher, Wilson involved his students and colleagues in his world, and many of them say he permanently changed their lives.

Take, for example, the book *The Limits to Growth*, published in 1972. It was based on a very early computer simulation of what would happen if world population, food production, industry, resource development, and environmental degradation continue to grow exponentially. The book put forth the then unthinkable idea that growth itself causes problems and that it must be deliberately limited.

The chain of events which led to the book began when Carroll Wilson introduced Jay Forrester, S.M.'45, head of the System Dynamics Group at M.I.T., to the Club of Rome—an independent, international forum for the "great issues." Forrester saw that the problems of growing complexity considered by the Club of Rome lent themselves to computer modeling. He produced two models and one of his collaborators produced a third on which some of Forrester's colleagues based *The Limits to Growth*.

The book triggered a storm of controversy by challenging the universal assumption that economic growth was the optimum scenario for all countries in all times.

Back at M.I.T., Wilson organized workshops, conferences, and seminars to explore the issues raised in this controversial work. One of the people who was inspired by the book to join Wilson's seminar at Sloan on "Critical Choices for the Future" was David Gray, a minister who had been studying finance at the Harvard Business School. Asked four weeks into the course to write a paper on "How would a sustainable social and economic system work when my grandchild is as old as I am now," Gray, produced a "grandchild paper" on a sustainable financial system 40 years down the road. This was at a time, he says, when "long-range" planning in the financial community meant looking 18 months into the future.

Wilson's lesson was that unless we have some concept of a truly good future, we are at risk of being overwhelmed by what are essentially transition problems. While "a grandchild paper" seemed like an almost bizarre ex-

PHOTO: CALVIN CAMPBELL FROM THE M.I.T. MUSEUM

A legacy of action on a global scale, concern for the major problems of man, and faith in the leadership of the young.

ercise in the very early 1970s, Gray remembers, this is now a recognized technique in policy design, referred to as "normative scenario planning."

As a teacher, Wilson never forgot the audience outside the ivyed walls. In 1973, when asked by a Congressional committee to testify on the range of issues raised in *The Limits to Growth,* Wilson wrote back to say he would be in Europe and unavailable, but help might be forthcoming from his seminar group in Cambridge. After some negotiation, members of the seminar agreed to provide 10 briefing papers for 10 days of testimony. "In 21 days, we wrote a book," Gray recalls.

"Working with Carroll Wilson was a life-shaping experience," Gray says. He and his wife, Elizabeth Dodson Gray, run the Bolton Institute for a Sustainable Future—publishing books, doing environmental projects for government and industry, and fulfilling a public education role. One of Gray's colleagues on the briefings to Congress, William Martin, '74, is now the third-ranking officer of the National Security Council in Washington. Other colleagues include John Strongman, S.M.'77, now with the World Bank, and David Korten, now with the Ford Foundation and the Agency for International Development (AID) in Indonesia.

Working for the Ugandans or the U.S.?

Following his departure from the AEC, Wilson had a continuing leadership role with the Washington-based Council on Foreign Relations, a high-level, private institution which seeks to understand issues and influence policy. Thus he was invited on a tour of the newly-emerging countries of Africa in 1959. The tour coincided with his acceptance of a bid from Mr. Johnson, who was then dean, to join the faculty of the Sloan School and the timing proved to be momentous for many of his students at M.I.T.

Wilson had seen in wartime the remarkable things accomplished by very young people thrust into positions of great responsibility. He saw in Africa a "talent vacuum" developing in the operational, middle management ranks of countries making the transition from colonialism to independence. And then at M.I.T., he was pressed by his students for some means for independent involvement in an international setting. Wilson synthesized all that into the African Fellows Program.

In typical Wilson fashion, he had the idea, located the funding, and did the leg work—travelling around Africa lining up jobs for the Fellows. The Fellows were apprenticed to African leaders on the condition that they be given real responsibility. As a result, they drafted law codes, negotiated national agreements with the World Bank, set up national airlines, and generally advised heads of state, often on issues with which they had no previous experience.

Wilson is said to have considered it the highest compliment to the program when the U.S. ambassador to Uganda complained that the African Fellow in Kampala was acting as if he were working for the Ugandans. "He is," Wilson agreed.

Among former African fellows, Richard Pigossi, S.M.'65, is vice-president of the Private Investment Co. for Asia, Jakarta; Michael Roemer, Ph.D.'68, is head of the Harvard Institute for International Development (now on a two-year assignment in Kenya); and Carroll Brewster (centerpiece of an eloquently detailed tribute to the program by John McPhee in *The New Yorker*) is president of Hobart and William Smith College. Constantine Simonides, enlisted by Wilson to help manage the program, is now vice-president of M.I.T.

The fellows program was discontinued in the mid-1960s, when the political climate in Africa became less hospitable to American advisors. But the 80 fellows (and their wives, whose talents also made them invaluable to African countries in need of every kind of skill) were welded by shared experience and elaborately orchestrated annual gatherings with Wilson into an enduring network which is the back-bone of the Wilson memorial activities.

Assessments of Global Problems

Wilson then turned to larger issues, pioneering a new format for studying and publicizing major scientific problems in world development. In 1970, for the first study, he assembled a multi-disciplinary group that produced, in one month, *Man's Impact on the Global Environment.* The study was an important catalyst of debate within the U.S. on the greenhouse effect and other major environmental consequences of technology, including the SST. The following year Wilson brought together 35 atmospheric scientists from 15 countries in Stockholm to produce *Inadvertent Climate Modification: Report of the Study of Man's Impact on Climate.*

Wilson next conceived of a process for engaging industrial and government leaders (in contrast to scientists) from many countries in making global assessments. He demonstrated the process in action during three years of leading a Workshop on Alternative Energy Strategies (WAES). His format involved enlisting the very top people in the countries with the most at stake in energy development (the president of Atlantic Richfield, for example), getting their commitment to meeting seven or eight times over the course of the study, requiring them to take on young "leadership apprentices," and getting the conference report, in book form, into bookstores in 15 countries within three months of the study's end. Issued in 1977, the WAES study outlined strategies to counter what it foresaw as an inevitable oil shortage.

Organization of the World Coal Study began in 1978, and that Wilson-led effort produced a report in 1980 entitled "Coal: Bridge to the Future." The essence of that study's conclusion was that precious oil could be saved by using coal in ways that were environmentally sound.

When Wilson died of leukemia in 1982, he was ostensibly retired, but in fact he was fully engaged in another of his classic studies, this time on conventional weapons as an alternative to the nuclear threat in NATO countries.

Behnke Appointed Admissions Director

Michael C. Behnke, dean of undergraduate admissions at Tufts University since 1976, will become the new director of admissions at M.I.T. on May 1, 1985.

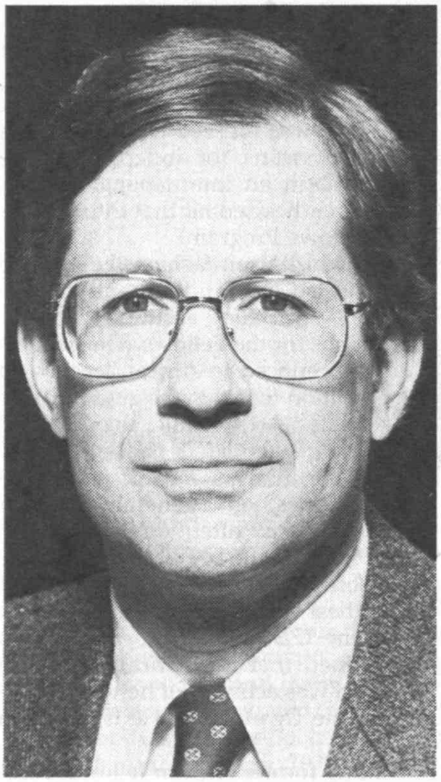
In announcing the appointment in December, President Paul E. Gray, '54, said, "This position is crucial to the quality and the range of interests of the students who come here, and thus, to the quality and effectiveness of our educational program, and I am delighted that Mr. Behnke has accepted our offer. . . . His enthusiasm for working with young people is contagious, and I am confident that he will be most successful in working with our faculty to attract students who, as in generations past, make M.I.T. such a special place."

Vice-president Constantine B. Simonides, '57, said that Behnke's selection followed an intensive national search to replace the retiring director, Peter H. Richardson, '48. Behnke was the first choice for the post, and was unaminously recommended by a faculty/student advisory committee chaired by Sheila Widnall, '60, professor of aeronautics and astronautics.

Behnke, who is 41, received the A.B. *cum laude* in American studies at Amherst College in 1965, and the M.A. in American civilization from the University of Pennsylvania in 1970. From 1971 to 1976, he was associate dean of admissions and dean of freshmen in alternating years at Amherst College, where he also taught American studies.

Competition Heating Up

In discussing his appointment in an interview, Behnke agreed that these are challenging times for admissions officers. There are the general problems of a shrinking pool of 18-year-olds, and the decline in the math and science skills of high school students, he says. In addition, M.I.T. faces the special challenges of recruiting more minority and women



M.C. Behnke

students and nurturing a better enrollment balance among all its departments, with the spectre of limited enrollment ahead if other measures do not produce the required balance.

M.I.T. "has an incredible advantage in that it is such a unique institution," Behnke says. But the importance of science and technology in modern life has led to a proliferation of college programs in these fields, he notes, and from M.I.T.'s viewpoint that sharpens the competition for good students.

Admission is an increasingly sophisticated process on every campus, Behnke says. The priorities are early contact, reinforcement, and establishing an institutional identity in every locality. He says that "most schools would envy M.I.T.'s network of volunteers," who work in just those areas.

The Institute has not done a lot in the way of producing videotapes to be available in high school guidance offices, and he wants to study that recruiting tool.

The search advisory committee was looking for an admissions director who is "research oriented," and Behnke defines that in two ways. It refers first to accountability, Behnke says: the office must have the research to back up its strategies. And second, he sees it as pointing to the importance of market research, with which he has had considerable experience. For example, he notes that a good marketing instrument is the questionaire M.I.T. sends to admitted students to help identify prospective students' reactions to M.I.T.

Behnke says that minority recruitment has lost the sense of urgency it once commanded in American higher education, but it is still a priority with him. His undergraduate experience at Amherst, where he took a year off to serve as education director for a community action program, was followed by teaching in an Upward Bound Program for low-income students at the University of Massachusetts and a two-year stint as a Peace Corps teacher in Sierra Leone. The experiences heightened his awareness of the needs of minority students.

In Off Hours, a Follower of the Muse

Behnke is a Winchester resident, where he serves on the board of the Winchester Program for a Better Chance and the Winchester Music School. He sings with the Boston Cecilia and several smaller vocal groups.

Behnke views with concern the fact that professional marketing and consulting services for college admissions have multipled in number and aggressiveness to the point where "I almost feel like an underdeveloped country surrounded by arms merchants." Not a day goes past that he doesn't get another marketing approach or another offer to redo Tufts' publications. "One told us we had too much text in our publications, but we hope to keep attracting students who read," Behnke said.

He should fit right in around here. □

When television viewers share this moment of triumph with Brad Waller, '85, winner of the 1984 2.70 design contest, they will understand the enthusiasm of President Paul E. Gray, '54. The competition will be a feature of the new PBS program, "Discover: The World of Science," at 8 p.m., Weds. March 6. PBS will also launch this monthly science magazine on Weds., Feb. 6 with a segment on the 1981 M.I.T. design competition. Consult your local listings to verify time and dates. (Photo by Donald M. Davidoff, '86)

New Endowment a Major Goal

By almost any standard, M.I.T. is grossly underendowed—far more dependent on current income than other major U.S. private universities.

M.I.T.'s present endowment is about $600 million, and David S. Saxon, '41, chairman of the Corporation, thinks the deficit is about a factor of two.

Paul E. Gray, '54, president, talks in units of $250 million—that much new endowment needed to support student financial aid (undergraduate financial aid last year required $5.9 million of M.I.T.'s unrestricted funds, and fellowship funds for graduate students are far too low), another $250 million to underwrite faculty salaries (in some departments faculty members have to assure as much as 40 percent of their salaries through the research grants they receive), and a significant fund (there is almost none now) to underwrite research and so eliminate the dependence on sponsors.

This emphasis on endowment needs was the theme of the annual meeting of the Corporation Development Committee late last year, at which both Saxon and Gray were principal speakers. They called it a return to fund-raising basics after as much as two decades in which most major M.I.T. fund-raising has been project-oriented, focussing on programs and buildings.

There are still plenty of such needs, too. Here are some noted by Gray for CDC members:

□ $10 million to complete the curriculum development work associated with Project Athena, the new expansion of computers into M.I.T. programs.

□ $40 million for a new physics building, to bring that department's widespread activities into a single focus.

□ Operating funds of $1 million a year for the new program in large-scale integrated systems whose facilities are being completed this winter.

□ About $1.5 million to complete a new $3 million design center for the Department of Mechanical Engineering.

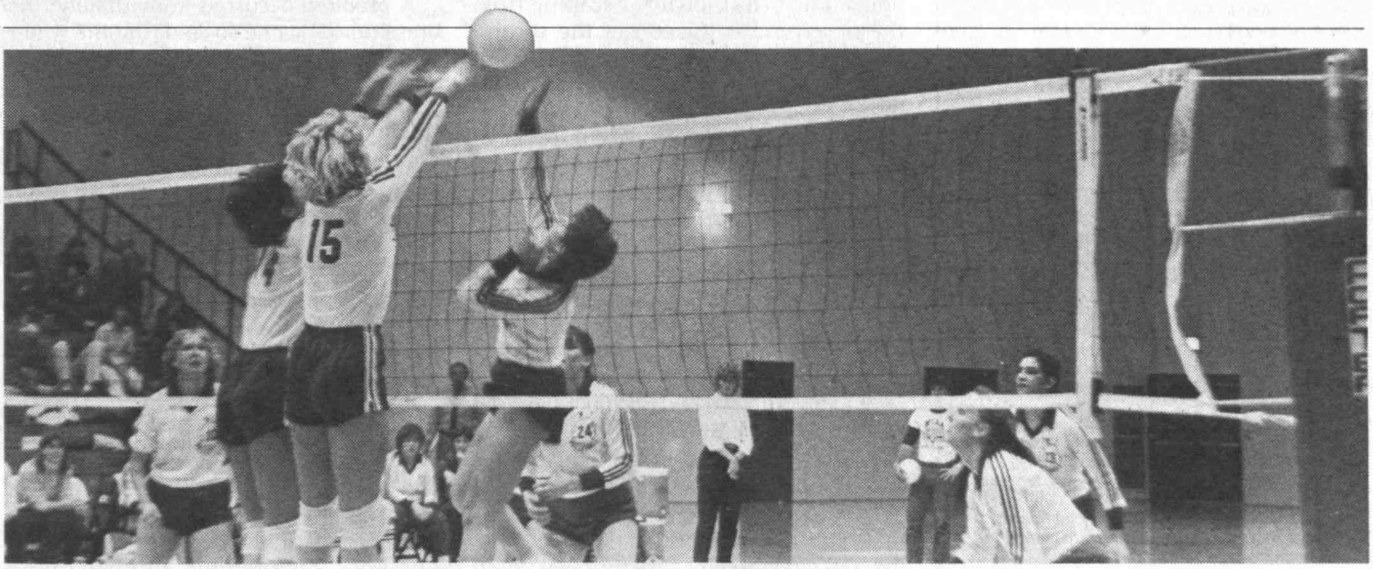
□ $4 to $5 million for renovations in the Department of Architecture.

□ $4 million to complete funding of the $27 million arts and media technology center, now nearing completion.

. . . Altogether a prodigious gift list whose fulfillment will depend on aggressive future fund-raising. One such thrust is a new effort to secure individual gifts of $100,000 and more.

The Alumni Fund has a crucial role in these efforts, too, said Mary Frances Wagley, '47, president of the Alumni Association. Its emphasis on small gifts from many alumni brings M.I.T. some $10 million a year, and—even more important—it paves the way for major contributions by cultivating commitment.

To conclude the session, CDC members presented Yaichi Ayukawa, '52, president of the Techno-Venture Co., Ltd, of Tokyo with the 1984 Marshall B. Dalton Award for "conspicuous and sustained service in the enhancing of M.I.T.'s financial independence." Ayukawa has provided "invaluable assistance and guidance" in M.I.T.'s efforts to gain support in Japan, said Saxon in making the presentation. □



For two years in a row, M.I.T. women's volleyball is runner-up national champion in Division III of the NCAA. At the finals late in 1984 at Elmhurst (Ill.) College, the women dropped a heartbreaking series. Lack of experience, said coach Karyn Altman, '78. But Ken Cerino, sports publicity director, called the season "one of the all-time greatest." (Photo: Victor J. Diniak, '86, from The Tech)

The Translucent Polychromatic Spectacle: Memoirs of a Hacker

BY MORTON GROSSER '53

I was the progenitor of the Giant Icicle (and, I blush to confess, quite a few other capers) during my tenure at Tech. The original icicle was grown during the winter of 1952-53—in January, I think—generated from the third floor bathroom of Crafts, at the Memorial Drive end of Senior House. I was the only senior involved, but I was assisted by an enthusiastic crew of sophomores.

The bathrooms in the Senior House had tall double-hung windows surmounted on the outside by a heavy sheet-metal cornice/flashing. Because of the condensation on the bathroom mirrors, we always kept the windows partially open at the top and bottom, regardless of outside temperature. The windows, which faced one wing of 100 Memorial Drive, were glazed with frosted glass, and the bathroom lights were usually on all night.

A Dormitory of Dickensian Charm

The inspiration for the icicle occurred one night when I was walking in the back entrance of Crafts. I glanced up and noticed that the moisture escaping from the open slot at the top of the second floor bathroom window had frozen along the cornice and formed a row of little back-lit icicles. They looked rather picturesque; indeed, they lent an air of Dickensian charm to the otherwise severe lines of the dorm. I found myself thinking of thatched roofs, half-timbered cottages, steak-and-kid, etc. Somehow an inductive leap occurred from the nostalgic wish-dream (I think we were in the midst of finals) to the idea of a huge, back-lit colored icicle, a sort of frozen aurora borealis that would make the inhabitants of 100 Memorial Drive gape in astonishment. Tacky, perhaps, even vulgar, but nonetheless astonishing.

It must have taken all of 30 seconds to recruit the entire third floor of Crafts from their homework. Before you could say dx/dt we were assembled in the bathroom, and the necessary hardware was appearing from those mysterious caches of junk in every M.I.T. closet.

We slipped a length of rubber tubing over the faucet and bound it in place with bus wire. (Later, when the technique had been proved, this set-up was replaced by a direct tap into the shutoff valve under the sink nearest the window.) The tube was coupled to a short length of thick-walled soft gas tubing, which was fastened to a vertical glass tube resting on the floor and wired to a piece of heavy white drawing board behind it. A flexible coupler at the top of the sight glass led to a one centimeter wide brass tube several feet long, which was first rested on the window sill and later supported by a camera tripod so that it was free to swivel.

We turned on the faucet and tried to adjust the flow rate and temperature so that water would drip out the end of the brass tube on the second-floor bathroom cornice below, run down to the end of any existing icicle, and freeze at the tip. Too much water, or too high a temperature, and the drop would simply fall off, or even erode the existing icicle. We wanted minimum increase of entropy and maximum growth rate of ice.

A problem occurred immediately: the brass tube became so cold that the water froze at its tip. It was soon equipped with a nichrome wire resistance heater monitored by a Heathkit VTVM. This proved to be a great breakthrough: we found that by using ordinary cold water and warming the delivery tube we could easily achieve the optimum growth rate. The tip of the tube was moved along the width of the cornice to distribute the curtain of ice uniformly.

For Aesthetics, We Need a Horse Needle

So much for technology; now for art. When a thick, broad base of ice had been laid down over the width of the cornice, we collected bottles of colored inks. A number 18 horse needle on a 20cc LuerLock hypodermic syringe (don't ask) was inserted into the thick-walled tubing. (This was later improved to a multiple-color installation.) Injections of colored ink could be monitored in the

sight glass and adjusted to provide intense bands of say, royal purple, or delicate washes of the palest mauve. A two-man team, one panning the drip tube and one controlling the color, could produce striae across the ice curtain that would have incited Turner to envy.

We certainly got responses from 100 Memorial Drive. Telephone calls to Senior House, notes and cards left at the dorm: "It's beautiful!" "What does it mean?" "Is it nuclear powered?" In a week of cold nights we grew the thing six feet long and the width of the window. It must have weighed a couple of hundred pounds, and we took to walking off the sidewalk in a wide arc when returning to the dorm.

The weather was, of course, rotten—perfect for growing giant icicles. By the end of the week the icicle was a thing of beauty, a translucent polychromatic spectacle, to coin a phrase. Unfortunately the window cornice had begun to make ominous creaking noises in the night. I had the feeling that if we added a few more grams of ice the whole side of the dorm would be torn out.

Still, we were loath to destroy it. Transient art wasn't a big deal in 1953, and for a few days we vacillated between identification with our creation and fear of expulsion. One would be standing quietly at the urinal at three in the morning and the window cornice would give one of those creaks and every hair on the back of your neck would stand up and you would think, "OhmyGod, there it goes." Eventually we were saved by an event rarer than the achievement of a stable fusion plasma: the sun came out. In two days, the giant icicle eroded to a pathetic dripping fringe. One morning there was a sudden sliding noise, and the base slipped off the cornice and shattered into confetti-colored shards on the sidewalk. □

MARTIN GROSSER, '53, holds an S.B. degree in general engineering and an S.M. in mechanical engineering. He now combines writing projects with consulting. His books include Gossamer Odyssey: The Triumph of Human-Powered Flight.

ILLUSTRATION: ELIZABETH SLOTE

How to Build a Quality Company? Quality People (and a Little Luck)

The most important single factor in building a quality company is quality people at all levels.

There are other needs—teamwork and communications, well-defined goals, a good product that the marketplace needs, effective marketing, high ideals, endurance, even good luck.

But it is good people that make possible all these things (except perhaps good luck), and "picking the best people is absolutely critical," said Amar G. Bose, '51, founding chairman of Bose Corp., Framingham, Mass. He spoke as one of the three keynote panelists at the M.I.T. Enterprise Forum's entrepreneurial workshop in Cambridge last fall.

Furthermore, said Bose, success breeds success: "The pride of people in being number one will keep you there. . . . There is no place for anyone who is content to be number two."

How do you pick such people?

Bose's answer: by determination and self-discipline. "You cannot believe you cannot get the best. Believe in it, and do it," he said.

"Hiring someone is a little like a courtship," warned Bose: we all too easily assume that weaknesses we perceive in the prospective spouse can be conquered in the fullness of the partnership. Not so. Look for qualities of character—"absolutely essential"; ask about "the best things he/she has ever done."

(Later in the day came a word of warning from Aaron Kleiner, '69, vice-chairman of Kurzweil Music Systems, Inc.: the hardest person to hire is the director of marketing and sales. Such people are "always selling," warned Kleiner—even selling themselves for jobs for which they are not qualified.)

What about luck? Bose admits it: his company's single largest increment of new business came through a partnership with General Motors to build high-quality stereo sound systems for top-of-the-line automobiles. And that deal originated in a chance converstation between Bose and then-President Jerome B. Wiesner, who at the time was a member of GM's Board of Directors.

"A quality company is more than they *and* us. *A sense of community and cooperation is essential."*

Other words of wisdom from the keynote panelists:

□ Teamwork in top management is essential, said Philippe Villers, S.M.'60, chairman of Automatix, Inc. "No one person can take care of all the essential functions" even in a new small business. Later in the day, panelist Ralph Linsalata of Weiss, Peck, and Greer, Boston, warned that he "would not deal with an entrepreneur who controls the company. I want a few other people involved in decision-making," said Linsalata, so that ideas and policies have had the benefit of some give-and-take among experts.

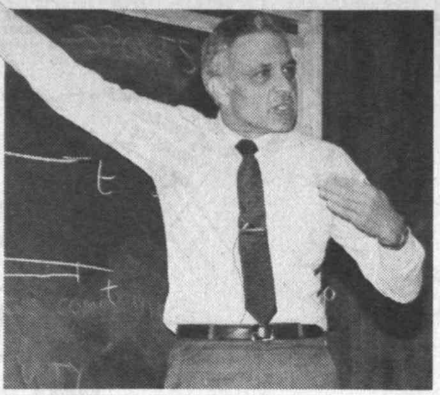
□ Quality products are an "absolute requirement" of a quality company, said William P. Murphy, Jr., '48, founding chairman of Cordis Corp. Products must be represented fairly (which is the reason why Cordis eschews the services of manufacturers' representatives, investing instead in its own sales force), and customers must feel well served by them.

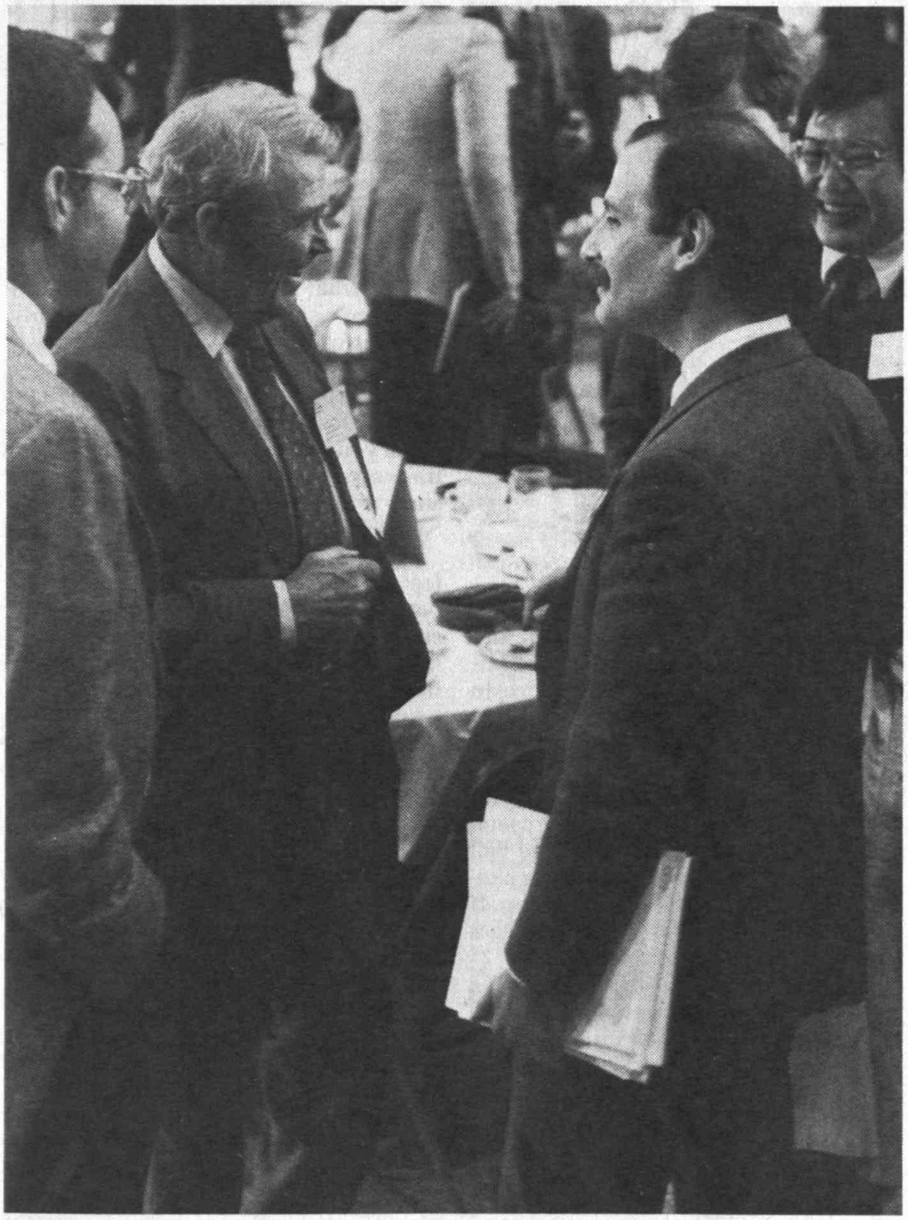
□ Young companies are "almost by definition in constant change," said Villers, but "people don't like to deal with change." That's one reason why small companies are so vulnerable. Even minor miscalculations can cause crises, and in Villers' experience "one crisis a year is not an abnormally high rate." But if these crises are handled effectively, no one outside the company need know about them. And good personal relations throughout the company are Villers' prescription. Indeed, he said, "a quality company is more than *they* and *us* . . . a sense of community and cooperation is essential." Villers himself runs every orientation session for new employees, and he's present every two weeks at evening discussions of corporate and management issues open to all.

The same message about the importance of a "human touch" in management came at lunch from William B. Hewlett, S.M.'36, vice-chairman of Hewlett-Packard Co. As H-P grew, said Hewlett, the company did everything it could to keep its workers' sense of participation. It constantly increased the number of its autonomous, small units, and it sought managers through promotion.

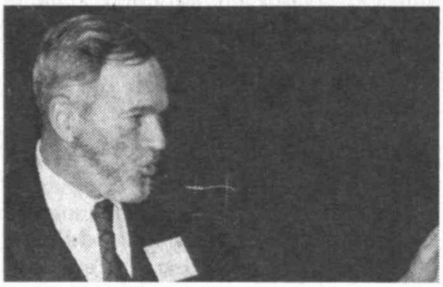
But finally, says Hewlett, growth overwhelmed that strategy, and in the 1950s H-P realized that it would have to go outside to recruit some MBAs. But it continues to cultivate a corporate culture that emphasizes quality, slow growth, and personal commitment—including liberal health insurance and monthly profit-sharing to all employees, the amounts of those bonuses being irrespective of salary. □

PHOTOS: DONNA PAUL AND JOHN MATTILL





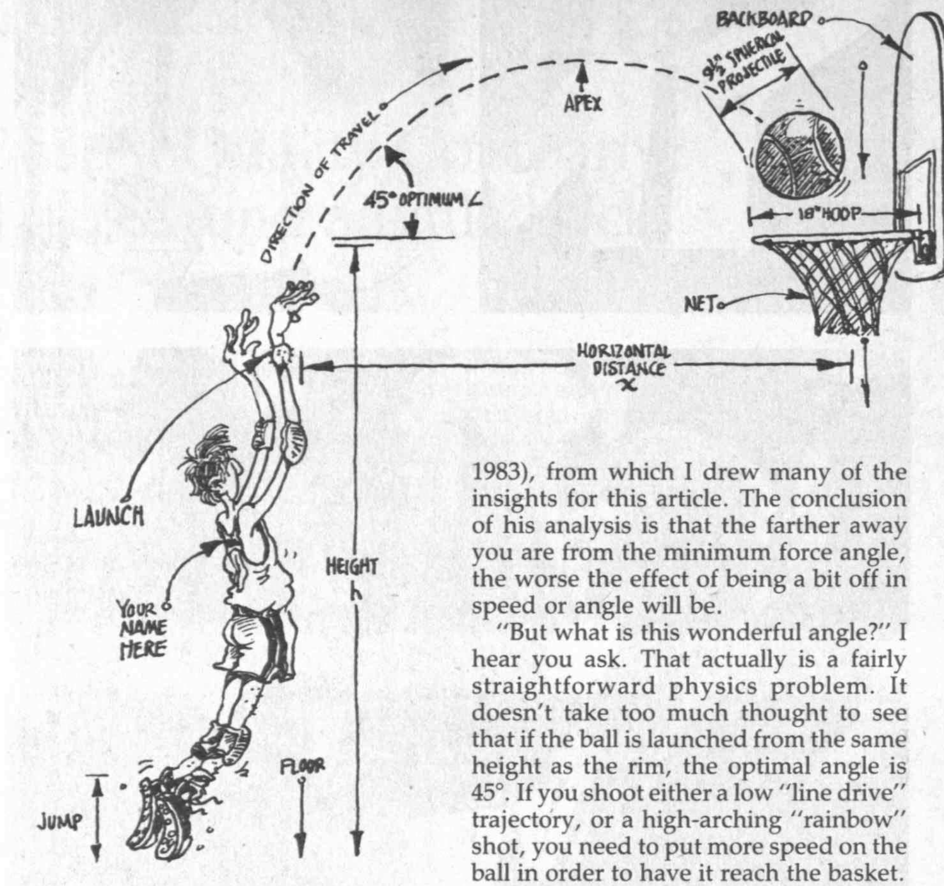
A stellar cast of speakers combined with the pull of entrepreneurship brought a sell-out crowd to the annual Enterprise Forum workshop at M.I.T. last fall. Above, keynoter William R. Hewlett, S.M. '36, of Hewlett-Packard. Opposite, Philippe Villers of Automatix. At the top of this page, Amar G. Bose, '51, of Bose Corp. and consultants Barbara A. Plantholt, '71, with Russell N. Cox, '48.



Among Enterprise Forum workshop experts (top to bottom): William P. Murphy, Jr., '48, Cordis Corp.; Judith H. Obermayer, Obermayer and Associates; Joanna Flint, Analog Devices; and Stanley R. Rich, Advanced Energy Dynamics, Inc.

MATTHEW DEADY

A Ph.D. From M.I.T. Won't Get You Into The NBA



"Apply physics to sports? What on earth for?" Well, being both a physicist and an avid sports enthusiast, I like to think that by using one's knowledge of physics, a better understanding of sports performance and strategy might be gained.

For starters, let's talk about basketball—in particular, the vexing problem of successful shooting. I have been playing basketball for more than 20 years, most of that spent in a vain search for a consistent "shooting groove." I'm willing to try anything, even physics.

Perhaps it would seem more like a physics problem if it were stated the way a student in 8.01 might encounter it.

"Problem 1. A spherical projectile of diameter 9 1/2 inches is launched from a height h. How should it be aimed so that it will pass through a hoop of diameter 18 inches mounted a horizontal distance x away and ten feet above the ground?"

Does that sound better? Of course, you can also score a basket if the ball bounces in off the rim or backboard, but this and other complications will be left to a later column.

In shooting the ball, the player controls three things: the horizontal aim, the vertical launch angle, and the initial speed of the ball. The fact that the hoop is almost twice as big as the ball determines the allowable variation in horizontal aim. But even if the hoop were 9 1/2 inches in diameter, there would be a whole range of vertical-angle/initial-speed combinations that result in a basket. For almost any vertical angle, there is a speed that will make the trajectory of the ball pass through the hoop.

Which of these angle-speeds to use is the question, and the key to good shooting might be summed up in a single phrase: "Let the minimum force be with you." For a variety of reasons, the launch angle that requires the least initial speed, and thus the least force to shoot, is the optimal angle at which to shoot the ball.

Reason number one is that the smaller the initial speed of the ball, the smaller the final speed will be. A smaller speed means a less violent bounce if the ball hits the rim, which gives it a greater likelihood of dropping through the hoop. It is no accident that many good shooters have a "soft touch" to their shots.

Reason number two is that the smaller the force needed to launch a shot, the easier it is to get the shot off in a hurry. During a jump shot, for instance, a quick release is essential.

Reason number three is more subtle. I don't care how good you are, any shooter is going to be a little off in angle and speed. But that's all right; there is a range over which these can vary and still result in a basket. (The hoop is bigger than the ball, remember.) By shooting at an angle close to the "minimum force angle," the shooter has the largest allowable range of error. For a detailed discussion of this point, I heartily recommend the book *Sports Science*, by Peter Brancazio (Simon and Schuster, 1983), from which I drew many of the insights for this article. The conclusion of his analysis is that the farther away you are from the minimum force angle, the worse the effect of being a bit off in speed or angle will be.

"But what is this wonderful angle?" I hear you ask. That actually is a fairly straightforward physics problem. It doesn't take too much thought to see that if the ball is launched from the same height as the rim, the optimal angle is 45°. If you shoot either a low "line drive" trajectory, or a high-arching "rainbow" shot, you need to put more speed on the ball in order to have it reach the basket.

But how many of us shoot from ten feet in the air? I certainly don't. For most of us, the launch point is at a height of seven or eight feet. This means a slightly larger angle (closer to 50°) will require the least force. But even a great leaper whose jump shot leaves the hand at 10 feet is best off shooting at 45°.

The higher you release the ball, the less you are trying to shoot "uphill" at the basket, and the less force you have to shoot with. The higher release point is part of the rationale for shooting jump shots (a more immediate reason is the necessity of shooting over your opponent). Besides their height advantage near the basket, tall people have a natural edge in outside shooting since they generally release the ball at a higher point. Somehow that seems unfair.

To practice your shooting, I do not recommend you head out to the court with a protractor or a sextant. Your wrist can tell you which shots are requiring the least force. This range of "easy shooting" is the one you want. Of course, it is not the ability to calculate trajectories, but rather the ability to control them that ultimately makes one a successful shooter. And that is just one of the many reasons why a certain 5'6" physics grad from M.I.T. is not in the NBA, but a certain 6'9" education major from Indiana State is. □

MATTHEW DEADY, PH.D.'81, DOES RESEARCH AT M.I.T.'S BATES LINEAR ACCELERATOR CENTER AND TEACHES AT MOUNT HOLYOKE COLLEGE.

ILLUSTRATION: JON MCINTOSH

NEWS FROM THE DEPARTMENTS

I

Civil Engineering

Plans are nearing completion for a two-day colloquium on new directions and challenges in civil engineering and the construction industry at M.I.T. on April 19 and 20. The events will mark the anniversary of the department at M.I.T., and all alumni have been invited to attend by Professor **Joseph M. Sussman,** Ph.D.'68, department head. Among the topics: the "infrastructure problem," toxic waste management, the changing transportation environment, improving productivity in the construction industry, and new issues in natural resources development.

M.I.T.'s Professor **Erik H. Vanmarcke,** Ph.D.'70, has won the 1984 Walter L. Huber Civil Engineering Research Prize of the American Society of Civil Engineers for his leadership in applying probablistic methods in civil engineering practice. . . . **Cordell W. Hull,** S.M.'57, who's had a distinguished career with Bechtel since joining the firm's financial services department in 1970, has been appointed to the executive committees of Bechtel's three principal operating companies and elected to the Bechtel Group's board of directors. He continues to serve as Bechtel senior vice-president and chief financial officer. . . . **John Kaufman,** S.M.'81, recently became registered as a civil engineer in California. . . . As president of World Systems Division, Communications Satellite Corp. (COMSAT) since 1983, **Joel R. Alper,** S.M.'59, is reponsible for the firm's international satellite communications and maritime services businesses. . . . **Neil Shifrin,** Ph.D.'80, is a partner and technical director of consulting at Cambridge Analytical Associates.

Dan Saltzman, S.M.'80, writes, "I will be leaving the Washington, D.C., staff of Congressman Ron Wyden to return to Portland, Ore., in early 1985." . . . **Raymond A. Ferrera,** Ph.D.'78, has been appointed assistant professor of civil engineering at Lafayette College, Easton, Penn.; he has previously held a similar position at Princeton. . . **Dario Valencia-Restrepo,** S.M.'72, is academic director of the Graduate Program in Water Resources at the Universidad National de Colombia, Medulun. . . . **Angel Silva,** S.M.'31, writes, "I was promoted to assistant vice-president for computer services at Parsons, Brinkerhoff, Quade and Douglas, Inc., engineers and planners of New York." . . . **Alan V. Trow,** S.M.'84; reports, "I am currently a lieutenant in the U.S. Army Corps of Engineers at Ft. Riley, Kans. I'm still very much the new guy on the block, but the civil engineering background I received from M.I.T. has served me very well."

Avinash C. Singhal, S.M.'61, has been promoted to full professor at Arizona State University (ASU), Tempe, and has been named director of the university's Earthquake Research Laboratory. Singhal recently spent three months at the University of Melbourne, Australia, setting up an earthquake laboratory, while also serving as chairman of National Science Foundation workshop on reasearch needs. . . . **Alberto B. Calvo,** S.M.'72, is manager of logistics engineering at the Analytical Sciences Corp., Reading, Mass. . . . **Walter R. Hylander, Jr.,** S.M.'50, is a resident civil engineer for Bechtel Corp. at the Grand Gulf Nuclear Plant in Mississippi, which went on line in October 1982. Hylander reports that he and his wife Jean own an antelbellum mansion and Christmas tree plantation on the Natchez Trace that are open to visitors and overnight guests all year.

Three deaths have been reported to the Alumni Association, with no details available: Major General **David B. Parker,** S.M.'40, of the U.S. Marine Corps, Washington, D.C., on March 30, 1980; and **Gerner A. Olsen,** of Scotia, N.Y., on April 26, 1984; and **Staunton L. Brown,** S.M.'38. a retired (since 1958) colonel in the U.S. Army who was a resident of Madison, Conn., on October 8. 1984.

II

Mechanical Engineering

The David Richardson Medal for significant contributions to technical optics came to **Erwin G. Loewen,** Sc.D.'49, from the Optical Society of America during the society's San Diego meeting last fall. Loewen, who is with Bausch and Lomb, Rochester, N.Y., was cited for contributions through work with conventional and holographic diffraction gratings. . . . The honor of fellow of ASME has been conferred on two alumni of the department: **Thomas A. Mitchell, Jr.,** '43, senior research associate at the Eastman Research Laboratories, Kingsport, Tenn.; and **Subhash K. Batra,** S.M.'61, associate professor of textile materials and management at North Carolina State University.

James Fleischhacker, S.M.'68, has resigned from AMP, Inc., where he was manager of the Components and Assemblies Division, to join and moved to Molex, Inc., Naperville, Ill., as director of marketing. . . . **Eric G. Newberg, Jr.,** S.M.'46, was the recipient of the National Commander's Annual Award as top individual in the Military Order of the World Wars at the national convention in Dallas, Tex., in August 1984. Newberg was also reappointed National Membership Committee chairman. . . . **James E. Masiak,** S.M.'73, received an M.B.A. from the Advanced Management Program at Michigan State University in June 1984.

Paul D. Rushfeldt, Sc.D.'78, writes, "I was recently appointed technical representative for Tritech International, Perry Offshore Inc.'s international organization. I also hold the positions of control group product line manager and engineering computer center department head." . . . **David A. Ulmstead,** S.M.'66, formerly at Putnam Management Corp., has joined the Asset Management Division of State Street Bank and Trust Co., Boston, as vice-president—chief research officer and head of the International Department. . . . **Jan A. Vetrop,** Sc.D.'53, has been promoted from chief engineer to executive vice-president—engineering and administration of Harza Engineering Co., Chicago. . . . **Jean-Louis Gauthier,** S.M.'81, is currently working in research and development for L'Air Liquide, makers of respiratory equipment in Jouy-en-Josas, France. . . . **Valentine Davidson,** S.M.'51, retired president of Hiac/Royce Co., Menlo Park, Calif, passed away on July 24, 1984; no further details are available.

III

Materials Science and Engineering

Add one at the top of the list to the alumni with principal roles in the 1984 Metals Congress in Detroit in September (*November/December, page A23*): **Donald J. Blickwede,** Sc.D.'48, was general chairman of the event.

Dwight L. Harris, Sc.D.'53, retired from Cyprus Industrial Minerals Co., a division of Amoco Minerals, in March 1983; he now lives in Westlake Village, Calif.. . . . **Richard A. Rawe,** S.M.'58, writes, "In August I received the ASTM

Ceramic Monolithics

A new program to develop high-technology ceramics for use in automotive engines and other high-temperature, high-stress applications is now being organized at M.I.T., with a five-year funding goal of $750,000.

One process, already supported under the program, involves blowing a mix of ceramic components in gaseous form through the beam of a laser. The laser's heat causes ceramic nuclei to form—millions of tiny particles of uniform composition and size. The absence of impurities and defects—of critical importance—suggests that the ceramics consolidated from these particles will be tough and strong—perhaps suitable for coatings in the hottest parts of engine combustion chambers, for example. Eventually could come what Jack A. Ekchian of the M.I.T. Energy Laboratory calls "monolithics"—all-ceramic components such as bearings or even cylinder heads.

The advantages: greater efficiency because of higher operating temperatures, lower-cost materials, and no radiators.

But with these gains will come a problem, says Ekchian: the need for new lubricants, because conventional oils simply won't survive at such high temperatures. Solids or gases may serve better, but Ekchian thinks lubricants may turn out to be "one of the toughest problems." □

Micros In, CPUs Out

After nearly 30 years of reliance on a single large time-shared computer—a concept pioneered there—the Laboratory for Computer Science is changing to a network of 30 powerful personal computers. The keys to this complex transition are "NuBus," a special communication standard developed at M.I.T. and licensed to Texas Instruments, Inc., and TRIX, a new operating system for linked microcomputers.

Together they are an approach to computer architecture that Michael L. Dertouzos, director of the laboratory, calls "revolutionary. ... like working with a timesharing system, but with the convenience of having one's own data base at hand, of being able to dedicate the machine to experimental use, and of never having to wait in a queue." □

Founders Award for the founding of Committee E-24 on fracture testing. On September 28 I was appointed McDonnell Douglas Corp. Fellow in fracture mechanics, one of 15 corporate fellowships extended for outstanding technical contributions since 1982." . . . **William F. Hosford, Jr.,** Sc.D.'59, reports that he is professor of materials and metallurgical engineering at the University of Michigan, a title he shares with three alumni, **Richard A. Flinn, Jr.,** Sc.D.'37, **Edward E. Hucke,** Sc.D.'51, and **Robert D. Pehlke,** Sc.D.'58. He is co-author of a text on metal forming published two years ago, and he writes, "I enjoy one or two wilderness canoe trips each year in Northern Ontario."

John R. Hutchins III, Sc.D.'59, received an honorary Sc.D. from Rutgers last spring and was elected to the Board of Trustees of Alfred University early this winter. . . . **Gray A. Miller,** Sc.D.'60, has been appointed director of the Materials Liaison Program and a research engineer at Lehigh University, Bethlehem, Penn. Miller was formerly a research engineer at Homer Research Laboratories of Bethelehem Steel Corp., Bethlehem, Penn. . . . **Janine J. Weins,** Ph.D.'70, has relocated her patent law and engineering consulting practice of Weins & Weins to Lebanon, N.H.

Andrew L. Johnson, Sc.D.'43, assistant professor of metallurgy at M.I.T. from 1938 to 1945 and since then active as a member of its Educational Council, passed away on October 13, 1984. Prior to Johnson's retirement, he was a technical director of a glass container industry research program and director of the W. Keith McAfee Laboratory at the Universal Rundle Corp., New Castle, Penn.

IV
Architecture

The automobile first changed our cities by creating the low-rise strip—the "visual junkyards of the 1950s," says Professor **Edward B. Wallace,** M.C.P.'78, of the University of Texas (Austin) School of Architecture. Then came freeways whose greater access transformed strip to mall; then came the high-rise strip and finally now the high-rise cluster—a collection of skyscrapers connected only by freeways to the original high-rise city center that gave it birth. Such clusters are a preview of the American urban landscape of the 21st century, says Wallace in the University of Texas' magazine *Discovery*.

A national policy for low-income housing in Sri Lanka and then project design for a typical housing development are the assignments of Professor **Nabell Hamdi** and **Reinhard Goethert,** M.Arch.'70, research associate, in the department at M.I.T.; Hamdi heads the department's Design and Housing Section and Goethert works in the Professional Practice Program. Their work is sponsored by the Sri Lanka government.

Delle R. Maxwell, S.M.'83, is producing a 3-D computer-animated "anchorperson" for a monthly TV program at NHK Television, Tokyo. . . . **Aron Faegre,** M.Arch.'76, is now a registered architect, civil engineer, and landscape architect in private practice in Portland, Ore. Faegre's projects range from a renovation plan for a YMCA camp to plans for a new downtown public-use heliport. . . . **Bharat Gami,** M.Arch.'79, has left Iowa State University to join Scwhinn and Associates, Architects, Bethesda, Md. . . . **Kenneth L. Kantor,** S.M.'79, has been appointed to the new position of director of advanced development and research for Teledyne Acoustic Research, Norwood, Mass., responsible for directing TAR's research and development activities worldwide.

Elizabeth Cordoliani, S.M.'83, an architect at I.M. Pei and Partners, is working in Paris on the firm's contract for extension of the Louvre. . . . **Charles W. Bardley III,** S.M.'83, is working for Stull & Lee, an architectural firm, Boston. . . . **Craig A. Whitaker,** M.Arch.'83, has started a construction business in Cambridge (Whitaker-Reisen Construction Corp.) with another Course IV graduate **Hank Reisen,** M.Arch.'83. The firm specializes in residental and commercial design, construction, and project management. . . . **James W. Burch,** M.Arch.'53, an archiect practicing in Annapolis, Md., passed away on April 10, 1984; no details are available.

V
Chemistry

A Short Introduction to Astronomy is the title of a new work by Professor Emeritus **Lewis Harris,** '20 (New York: Vantage Press, $12.95), published late last year. Harris, who retired in 1964 after a 36-year career as a member of the department, now lives in Weston, Mass. . . . Two new assignments at M.I.T.'s George R. Harrison Spectroscopy Laboratory: **Jeffrey I. Steinfield,** '62, professor of chemistry, is now assistant director for scientific coordination, and **Ramachandara R. Dasari,** who joined the laboratory in 1980 from the Indian Institute of Technology at Kanpur, is assistant director for project coordination.

John E. Sheats, Ph.D.'66, is currently on sabbatical from Rider College pursuing research on the process of oxygen evaluation in photosynthesis at Princeton University. . . . **Daniel Reger,** Ph.D.'72, has been promoted to full professor of chemistry at the University of South Carolina. Reger is the author of more than 40 research papers in his specialty area of inorganic chemistry and is co-author of two freshman college texts. . . . **Robert W. Gleason,** Ph.D.'60, professor of chemistry and dean of sciences at Middlebury College, Vt., has been appointed to fill the new post of dean of the faculty. He's completed 24 years of service on the Middlebury faculty.

VI
Electrical Engineering and Computer Science

Paul R. Drouilhet, Jr., E.E.'57, who joined Lincoln Laboratory in 1959 to work in air-ground communications, has been named assistant director of the laboratory. Drouilhet's activities moved to the field of air traffic control in the 1970s, and he has most recently headed Lincoln's Surveillance and Control Division.

Dean F. Peterson III, Ph.D.'71, of Steinbrecher Corp. was the speaker late last fall on systems of millimeter-wave power generation for communications applications for the Microwave Theory and Techniques Chapter of the Boston Section, IEEE. Peterson first worked in the field at Lincoln Laboratory and then for seven years as a member of the electrical and computer engineering faculty at the University of Michigan before taking his present job last year.

Raymond S. Stata, '57, president of Analog Devices, Inc., has rejoined his two authors from an earlier book, *Global Stakes,* James Botkin and Dan Dimancescu, in *The Innovators: Rediscovering America's Creative Energy* (Harper and Row, 1984, $16.95). The new work includes a series of case studies of companies and regional innovation incentives, stressing that—given the scope and complexity of modern technology—many people and elements of the political and industrial environment must come together to make possible successful entrepreneurship innovations. David Warsh in the *Boston Globe* calls the book "a savvy *tour d'horizon* of high-tech developments."

Lynne Ann Molter, a doctoral candidate in the department at M.I.T., was honored by the Optical Society of America last fall with its Newport Research Award for the quality of her thesis research into multiple waveguide lens theory.

"Vintage prints" by **Harold E. Edgerton,** '27, were exhibited at the Pace/Macgill Gallery in New York for six weeks at the end of 1984. Meanwhile, Edgerton was among the most popular lecturers on the campus—speaking early in the fall on Stonehenge and at the end of the term on the history of strobe photography. A color videotape of many of his works—underwater time-lapse photography, high-speed motion pictures of milk drops, and many other photographic subjects—has now been completed under the auspices of the Alumni Association, and copies in half-inch VHS format are available from the Association at $20.

William R. Hewlett, S.M.'36, co-founder and vice-chairman of the board of Hewlett-Packard Co., received the Illinois Institute of Technology's Herald Award last fall. Hewlett was recognized for his "outstanding dedication and service to human progress." . . . He has "unsparingly given of his time, thought, and effort to activities directed to the public good." . . . **Roger R. Schell,** Ph.D.'71, has recently joined Gemini Computer, Inc., Carmel, Calif., as vice-president for engineering. . . . **Louis Weinberg,** Sc.D.'51, reports, "I have decided it's about time to finish my book on graphs and matroids before every other professor does." He is professor of electrical engineering at the College of the City of New York, CUNY. . . **Dean H. Vanderbilt,** Ph.D.'70, is currently vice-president of product development for Fox and Jacobs, Inc. (homebuilders), and an elected member of the Dallas City Council.

"It's a major breakthrough. There is nothing else on the market that can emulate a $50,000 workstation for such a low price." The speaker is **Arthur Crooke,** S.M.'57, of Concord, Mass., who's describing his new Logic Design Processor. It's a computer-aided design program especially planned for the manufacture of digital systems, Crooke says.

Lewis D. Collins, Sc.D.'68, is employed as a hardware engineering specialist in the research and development operations of Wang Laboratories, Inc., Lowell, Mass. . . . **Amos E. Joel, Jr.,** S.M.'40, a switching consultant at AT&T Bell Laboratories, Short Hills, N.J., has been awarded the 1984 Columbian Medal from the city of Genoa, Italy. Joel was cited for his work in "telecommunications switching and for his role in the study and planning of the world's first system using stored program control."

Arthur C. Nisula, S.M.'46, a retired electrical engineer, passed away on September 3, 1984, in Duxbury, Mass. Nisula was a lieutenant in the U.S. Navy Bureau of Ordnance during World War II and a member of the Massachusetts Society of Professional Engineers. . . . **Robert Kenneth Bullington,** S.M.'37, of Colts Neck, N.J.,

passed away on May 30, 1984; no details are available.

VI-A Program

Monday and Tuesday of Thanksgiving week the department hosted the biannual meeting of its Visiting Committee. These leaders from academia and industry in the field of electrical engineering and computer science review, with faculty and student input, how Course VI is functioning. Of the 21 members five are VI-A graduates, namely: **John G. Linvill,** '43, professor of electrical engineering and co-director of the Center for Integrated Systems at Stanford University; **Lawrence G. Roberts,** '59, president of DHL Corp., San Mateo, Calif.; **Raymond S. Stata,** '57, president of Analog Devices, Norwood, Mass.; **William R. Thurston,** '44, president of GenRad, Concord, Mass.; and **Andrew J. Viterbi,** '56, president of M/A-COM Linkabit, Inc., San Diego.

This year's officers of the M.I.T. Tau Beta Pi Chapter include two VI-A students: Elizabeth C. PATTERSON '85 is Vice President and Kathleen A. WIENHOLD '85 is Corresponding Secretary. As a major project, the Chapter is again raising funds to sponsor free student admission to Boston's Museum of Science.

So far, Christmas greetings have been received from: Geoffrey J. BUNZA '74, GenRad, Scottsdale, AZ; John F. COOPER '74, Dolby Labs., San Francisco, CA; E. Thomas CRAIG '81, ROLM Corp., Santa Clara, CA; Edward C. GIAIMO '74, Zetron, Bellevue, WA; Grace LEE '83, Rutgers Medical School, NJ; and James A. LUTZ '84, currently on VI-A Assignment at Sentry/Schlumberger, ATE, San Jose, CA.

At the first business meeting the question of the department's inabilty to expand VI-A was raised and discussed. A number of VI-A undergraduate and graduate students were among groups appearing before the committee.

The honor of a Rhodes Scholarship has come to one of our current graduate students, **Mark C. Jennings,** '84. It was awarded by the board of Natal, South Africa. Mark expects to receive his S.B. and S.M. degrees in June 1985 and hopes to attend Oxford University this coming fall. We wish him much success!

This award led to our wondering how many other VI-A's, in years past, have been Rhodes Scholars. Inquiries brought forth four names: **Vernon G. Lippitt,** '38; **J. Ross MacDonald,** '44, **Vincent L. McKusick,** '47, and **Eugene B. Skolnikoff,** '50. It would be nice to have a complete list on file, so we request that you write if you know of others.

Among three M.I.T. winners of scholarships from the National Society of Women Engineers is **Gaile G. Gordon,** '85. This is the first time M.I.T. students have won so many scholarships in the SWE national competition.

Effective January 1, 1985, **Paul R. Drouilhet, Jr.,** '54 became assistant director of Lincoln Laboratory; Paul has been a member of the technical staff at Lincoln Laboratory since 1959. . . . Another Lincoln appointment, made last fall, is **Vincent W. S. Chan,** '71, to leader of the Optical Communications Technology Group. This group is involved in coordinating research and development of space optical communication systems.

VI-A's astronaut, **William B. Lenoir,** '61, has recently left NASA and joined the international management and consulting firm of Booz, Allen and Hamilton, Inc. as a principal in the company's space-systems practice in Arlington, Va. . . . A late October letter tells us that **Vincent H. Tobkin,** '73, has gone into venture capital with Sierra Ventures of Menlo Park, Calif., following eight years in San Francisco with McKinsey and Co.

A chance visit to the Placement Office in November brought a meeting with **Johnny Low,** '78, who was interviewing for his company, MITRE Corp. . . . Also interviewing for his company, Eastman Kodak Research Laboratories, Physics Division, was **Kenneth A. Parulski,** '79, who came by for a VI-A visit November 1.

Here on a business visit representing Bell Communications Research (Bellcore) to discuss the possibility of their joining the VI-A Program (as part of the AT&T divestiture of Bell Labs) was **Chester M. Day, Jr.,** '58. Chet's father ('28) graduated from VI-A and Chet Jr.'s son, Stephen M., is a sophomore in Course VI and hopes to apply for VI-A this spring.

In mid-October, **Gary K. Montress,** '69, joined the Raytheon Company's Research Division, Lexington, Mass. Gary did his VI-A work at Raytheon and upon graduation was employed at the Research Center of United Technoloiges, Inc., Hartford, where he worked before moving to Raytheon. Gary and wife Sally keep in regular touch with the VI-A Office.

Other VI-A visitors signing our guest book included: **David T. Chan,** '83, with VTI, Burlington, Mass.; **Dean R. Collins,** '58, with Texas Instruments in Dallas; **Daniel G. Jablonski,** '76, with the Naval Surface Weapons Center, White Oak Laboratory, Md.; **Joshua L. Koslov,** '79, with RCA Laboratory, Princeton; and **Michael H. Landmeier,** '84, with Megatest, San Jose, Calif.—John A. Tucker, Director, VI-A Program, M.I.T., Room 38-473, Cambridge, MA 02139

VII

Biology

Mary Lou Pardue, professor of biology at M.I.T., is one of three new members (four years) of the National Advisory General Medical Sciences Council. The council, made up leaders in biological and medical sciences education, health care, and public affairs, reviews applications for research and training grants. Dr. Pardue's research is on the structure and function of chromosomes and gene activity during development; she is a past president of the Genetics Society of America and president-elect of the American Society of Cell Biologists.

Up to $600,000 for predoctoral fellowships in the department at M.I.T. is likely to come during the next seven years from the Lucille P. Markey Charitable Trust; already $360,000 has been committed for three classes of students beginning with the current academic year. The late Ms. Markey was the owner of Calumet Farm, the world-famous Kentucky racing stables, and she left the bulk of her estate in a trust to be used for basic medical research.

Clemens E. Prokesch, S.M.'45, writes, "I am in full practice of internal medicine in New London, Conn. I have also been president of the Thames Stamp Club here for 25 consecutive years and am in my second year as vice-president of the German Society of Eastern Connecticut." . . . **Tom Berman,** Ph.D.'64, is research professor at Kinneret Limnological Laboratory and the Israel Oceanographic Institute, Haifa, studying microplankton ecology in marine and fresh waters.

X

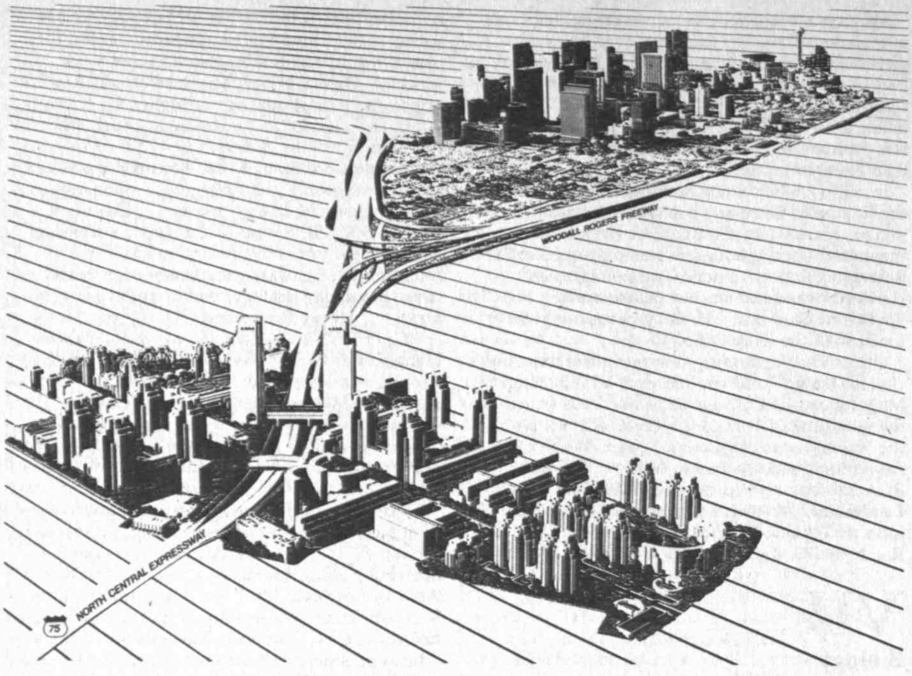
Chemical Engineering

Funding is now being sought for a $150,000 annual lectureship honoring Professor Emeritus **Hoyt C. Hottel,** '24, who has been an active member of the department's faculty since completing his master's degree. Former students proposing the tribute say Hottel "has inspired students for over 60 years by his constant probing for innovative solutions to practical problems and his uncompromising search for excellence. As a teacher," they write, "he posed problems that pushed students to their limits and beyond."

A new round of public attention came to **Jennie R. Patrick,** Sc.D.'79, as the first black woman to receive a doctorate in chemical engineering in the U.S., late last fall when CIBA-GEIGY presented a portrait of Patrick to her alma mater, Tuskegee Institute. Patrick was named in CIBA-GEIGY's "exceptional black scientist" series last year. She now works at the Philip Morris Research Center, Richmond, Va. In addition to this scientific work, however, Patrick is devoting substantial effort to improving educational opportunities for minority youth and women and encouraging such students to pursue scientific careers.

Dominick Sama, Sc.D.'54, has been promoted to full professor in the College of Engineering at the University of Lowell, Mass. . . . **Dennis Revelotis,** S.M.'58, former executive vice-president has been promoted to president at M/A-Com, Inc., Burlington, Mass., responsible for long-range planning, strategy, and financial performance. . . . **Henry Rockwood,** '32, writes, "In the spring of 1983 Ann and I visited Japan, Taiwan, Hong Kong, Canton, Bangkok, Penang, and Singapore, and loved it all. In the summer of 1984, we visited Moscow, Leningrad, and Baku on the Caspian Sea and took a 10-day cruise from Rostov-on-the-Don to Kazan on the Volga via Ulynov and Volgograd. A magnificant trip worth repeating."

Two alumni with major responsibilities as president and vice-president respectively, of Research Industries, Inc., Alexandria, Va., have joined the board of Halifax Engineering, Inc., Alexandria: **Arch C. Scurlock,** Ph.D.'43, and **John H. Grover,** S.M.'43; Scurlock is serving as chairman of Halifax's board. . . . **Robert J. Richardson,** Sc.D.'54, who is president and director of Bell Canada Enterprises, Inc., has been elected director of the New York Life Insurance Co. . . . **Bayard T. Storey,** S.M.'55, is professor of reproductive biology and physiology in the Department of Obstetrics and Gynecology at the University of Pennsylvania School of Medicine.



The tall buildings of City Place linked to the original city center of Dallas by expressway are typical of what Professor Edward B. Wallace, M.C.P.'78, of the University of Texas (Austin) School of Architecture calls a high-rise cluster. He says this will be the typical urban landscape of the 21st century.

XI

Urban Studies and Planning

Alan Sager, Ph,D.'79, writes, "I've been appointed an associate professor at Boston University School of Public Health and elected to head the Public Hospital Caucus of the American Public Health Association." . . . **Tomasz Sudra,** Ph.D.'72, is officer in charge of training at the United Nations Center for Human Settlements (HABITAT), Nairobi, Kenya. . . . **Jeffrey Davison,** M.C.P.'83, has been appointed to the Massachusetts Technology Development Corp., Boston, a public agency providing venture capital financing to early-stage technology-based companies in the state. . . . **Philip Shapira,** M.C.P.'79, is completing his doctoral dissertation on industrial restructuring in California at the University of California, Berkeley.

XII

Earth, Atmospheric, and Planetary Sciences

Edward C. Monahan, Ph.D.'66, has added a second doctorate to his pedigree—an Sc.D. in July 1984 by the National University of Ireland, based on 30 articles he lodged with N.U.I. in 1983. . . . **Tamara A.S. Ledley,** Ph.D.'83, writes, "Currently I am a research associate in the Department of Space Physics and astronomy at Rice University, Houston. My research focuses on climate change as it is affected by and reflected in sea ice and ice sheet variations. This includes examining the effect that smoke produced in a nuclear war may have on sea ice and thus on climate." . . . **William H. Haggard, II,** '42, is president of Climatological Consulting Corp., which provides meteorological investigations and expert testimony for attorneys in litigation where weather was a factor.

Peter R. Tatro, Ph.D.'66, is a corporate vice-president with Science Applications International Corp., McLean, Va. . . . **John R. Seesholtz,** Ph.D.'68, is a Navy oceanographer stationed at the Naval Observatory, Washington, D.C. . . . **Gilbert D. Brinkerhoff,** reports, "Shortly after receiving my S.M in meteorology, I enrolled in the George Washington University School of Medicine. I am presently in the private practice of dermatology on Cape Cod, Mass."

XIII

Ocean Engineering

The 1984 Ship Structure Symposium was dedicated to Professor **J. Harvey Evans** for his exceptional service to the maritime industry during a long and successful career. The symposium was sponsored by the Ship Structure Committee of the Society of Naval Architects and Marine Engineers. . . . Captain **Bruce C. Skinner,** Nav.E.'65, was appointed head of the Department of Engineering at the U.S. Coast Guard Academy in June 1984. . . . Lieutenant Commander **William M. Shepherd,** Ocean E.'78, a sea-air-land officer (Navy SEAL), is the first non-aviation navy person selected by the National Aeronautics and Space Administration for astronaut training. Shepherd commanded Special Boat Unit 20 in Special Warfare Group Two, Naval Amphibious Base, Norfolk, Va., before reporting last July to the Lyndon B. Johnson Space Center, Houston, for training as an astronaut mission specialist. It could be three to four years before Shepherd makes his first shuttle flight, but he says he feels fortunate to be a part of the space program.

Commander **John C. Scalzo,** Ocean E.'73, is on the staff of the Commander, Naval Air Force Atlantic Fleet, Norfolk, Va., responsible for aircraft carrier maintenance. . . . **George A. Uberti,** S.M.'54, program manager at National Steel and Shipbuilding, San Diego, was recently honored by election as honorary vice-president for life of the Society of Naval Architects and Marine Engineers. . . . Lieutenant Commander **John N. Edkins,** Ocean E.'80, is a Canadian Navy exchange officer working at the David Taylor Naval Ship Research and Development Center, where he is the development manager for the Advanced Surface Ship Evaluation Tool (ASSET), a major U.S. Navy ship design and evaluation computer program. . . . **Vernon C. Honsinger,** Nav.E.'62, writes, "I recently moved to the position of director of contract administration at Robert E. Derecktor of Rhode Island, Inc., a shipbuilding and repair yard located in Newport."

Commander **Robert A. Baeder,** S.M.'71, is submarine officer assigned to the *U.S.S. Henry L. Stimson*. . . . **Richard K. Anderson,** S.M.'36, writes, "I am making a fairly good recovery from a cancer operation last January." . . . **Eugene G. Verrett,** S.M.'60, reports, "I am now the manager of the Engineering Department of the SSSRC Royal Saudi Naval Forces in Kanb, Jubail.—Patricia A. LeBlanc-Gedney, Administrative Officer, Course XIII, Room 5-228A, M.I.T., Cambridge, MA 02139

XV

Management

Patrick D. Centanni, S.M.'81, has left Research Planning, Inc., Cambridge, to become assistant vice-president and manager of market information at the State Street Bank, Boston. . . . **Carl P. Lehner,** S.M.'80, writes, "Sandra and I had our first son, Myril Hans, on August 25, 1984, and we're now learning the joys of parenthood. I had a great trip to China in the spring to climb Xixapangma—the 13th highest peak in the world. We got six to the summit (26,400 ft.), and I got to 23,000 ft.". . . **Michael Kasinkas,** S.M.'82, was an unsuccesful candidate for the Minnesota House of Representatives last November. . . . **Jay Petschek,** S.M.'82, has recently joined Laderburg, Thalman & Co., to do both corporate finance and securities research. . . . **Nathan E. Jones,** S.M.'78, is a stockbroker with Merrill Lynch, San Diego, Calif. . . . **Curt P. Kohlberg,** writes, "I have been appointed financial services specialist with Epsilon, the largest computer-based direct marketing firm, in Burlington, Mass." . . . **Kathryn E. Hoff-Patrinos,** S.M.'80, writes, "I am enjoying my law practice at Milbank, Tweed, Hadley and McCloy, Washington, D.C." . . . **Victoria M. Johnson,** S.M.'82, recently joined Milestone Associates, a growing real estate management firm, as a financial manager.

Susan K. Sudman, S.M.'75, formerly vice-president of consulting services for Amherst Associates, Inc., Chicago, has been appointed practice director—health care management consulting in Peat Marwick's St. Louis, Mo., office. . . . **Lynton B. Manssen,** S.M.'82, is manager of the Applications Software Division of Addison Wesley Publishing Co., Reading, Mass.

Senior Executives

Keith J. Martin, '68, retired last October after 38 years of service in England, the United States, and overseas with companies of the Royal/Dutch Shell Group. . . . **Andrew C. Knowles III,** '76, has been appointed to the newly created position of corporate vice-president of Pr1me Computer, Natick, Mass., to focus primarily on new ventures. Knowles previously was president and chief executive officer of Lexidata Corp., Billerica, Mass.

Management of Technology Program

Bruce D. Gobioff, S.M.'84, has been given new responsibility in the Gaithersburg Division of IBM, where he is now manager of the Wideband Product Development organization. He writes he has been doing a lot of traveling to Santa Barbara and Raleigh in relation to his work. . . . **Moises J. Goldman,** S.M.'84, was in Boston for two weeks in November while his son Joshua underwent

corrective heart surgery. He saw **Erik Chaum,** S.M.'84, while here and was updated on the progress of Erik's company—10 Point Systems, Inc. . . . **John A. Harrison,** S.M.'82, and his wife Bonnie write that the new addition to their house is coming along. It seems John is doing all the work himself, and the addition is bigger than the original house!

Wesley R. Robinson, S.M.'84, wrote in October: "I am quite nicely settled into my new job in Greece. I like the area and the job and have no desire to leave." He hopes to do some traveling to Vienna soon and to look up Professor Tom Lee who is there in his new position with IIASA. . . . **Dennis Shea,** S.M.'84, has been named project manager at the Center for Naval Analyses reporting to the vice-president of operations. He says he is responsible for directing the research efforts of six analysts and is already using what he learned at M.I.T. to help him manage professionals in a consulting environment. He and the family have moved from his previous home in Virginia Beach to a new house in Burke, Va. . . . **Shjang-zhi Wu,** S.M.'84, moved to the Washington, D.C., area in the middle of December to take on his new position as a young professional with the World Bank, where he is working on a manufacturing project for the People's Republic of China.—Jane Morse, Program Manager, M.I.T., Room E52-125, Cambridge, MA 02139

XVI

Aeronautics and Astronautics

Dennis Mathaisel, Ph.D.'81, has been appointed assistant professor in the Management Science Division at Babson College, Wellesley, Mass. Formerly, Mathaisel was a teaching assistant and more recently research associate and lecturer at M.I.T. Mathaisel was also the founding director of an M.I.T.-industry cooperative research program—a consortium of nine international companies and institutions—supporting studies in modeling air transportation systems. . . . **Jeffrey R. Kurland,** S.M.'70, is vice-president for the Telecommunications Systems Division at the First National Bank of Maryland. . . . **Henry F. Lloyd,** S.M.'46, writes, "After 30 years in the U.S. Navy, still a college administrator at Flagler College, St. Augustine, Fla., with no plans for retirement as yet."

Ralph E. Ekstrom, S.M.'56, has been appointed chairman of the Engineering Mechanics Department at the University of Nebraska.

XVIII

Mathematics

As president of the Institute for Mathematics and Society of the Society for Industrial and Applied Mathematics (SIAM), **Donald L. Thomsen, Jr.,** Ph.D.'47, has a major role in a new $716,000 study of acid rain for the Environmental Protection Agency. The goal: new mathematical and statistical ways to detect and evaluate acid rain impacts and trends. Research under the program will be conducted at Rand Corp., Stanford, and the University of British Columbia; it's the fifth major study of environmental pollution conducted by SIMS for the EPA.

Two alumni have recently been appointed to new faculty positions at Lehigh University, Bethlehem, Penn.:

☐ **Bennett Eisenberg,** Ph.D.'68, has been promoted to full professor of mathematics. Eisenberg, a faculty member since 1972, formerly was an instructor at Cornell University and a visiting assistant professor at the University of New Mexico.

☐ **David L. Johnson,** Ph.D.'71, has been appointed associate professor of mathematics. Johnson was formerly an associate professor at Texas A&M; he specializes in differential geometry and algebraic geometry.

Joseph J. Buff, S.M.'77, has joined the Fixed Income Analytical Research Group at Morgan Stanley and Co., New York.

XXII

Nuclear Engineering

Richard K. Lester, Ph.D.'79, associate professor of nuclear engineering, is now in the first year of a two-year appointment to M.I.T.'s Atlantic Richfield Career Development Professorship in Energy Studies. His work under the professorship deals with the relationship between industrial structure and technological performance in the electric power sector.

A. Halim Kazi, Ph.D.'61, is chief investigator at the Dulse Radiation Directorate, Combat Systems Test Activity, Aberdeen Proving Ground, Maryland, where he is involved in a wide variety of radiation test programs for the U.S. and NATO allies.

Lieutenant Commander **Mark J. Harper,** U.S.N., S.M.'76, is serving as engineer officer aboard the *USS Philadelphia* (SSN690), nuclear-powered fast attack submarine. . . . **Hamid A. Rafizadeh,** Ph.D.'70, writes, "I am currently assistant treasurer of the Dayton Power and Light Co. Prior to that I held the positions of manager of financial operations and manager of engineering. From a nuclear engineering prospective, I am involved with Zimmer Station, which is being converted from a nuclear to coal-fired plant." . . . **James K. Liming,** S.M.'83, is an engineering consultant with Pickard, Lowe, and Garnick, Inc., performing risk, reliability, availability, and maintainability analyses.

Technology and Policy Program

Jean Bernard Caen, S.M.'81, has recently been appointed marketing manager of the French subsidiary of Comshake, Inc., a computer software firm. . . . **Tom Sofyanos,** S.M.'80, has been transferred to New York City to act as U.S. representative of Det Norske Veritas of Oslo, Norway. . . . **Bob Chen,** S.M.'82, spent the past summer as a consultant with the National Academy of Sciences, where he worked on the International Geosphere/Biosphere Program and on a climate-related data committee.

Paul L. Chernick, S.M.'74, told the Maine Office of the Public Advocate last fall that the Seabrook nuclear reactor, of which the Central Maine Power Co. is part owner, "is unlikely ever to pay back the initial investment, even without considering the time value of money." Mr. Chernick's analysis suggests that Seabrook power will not be cheaper than power from oil-fired boilers at least until 2006, and he concludes according to the *Central Maine Morning Sentinal* that New England electricity consumers "have very little to gain from completing the plant and enormous potential losses." Chernick is associated with the consulting firm of Analysis and Inference, Inc., of Boston.—Richard de Neufville, Chairman, Technology and Policy Program, M.I.T., Room 1-138, Cambridge, MA 02139

Program in Science, Technology and Society

Can automation, microelectronics, and other fruits of high technology render obsolete such images of industry as the assembly line, giant conglomerates, and mass production? That "new industrial order" isn't assured, but it is a goal worth reaching for, write Professors **Michael J. Piore** and **Charles F. Sabel** in an important new book—*The Second Industrial Divide: Possibilities for Prosperity* published last fall by Basic Books ($12.95). Piore is an economist, Sabel a political scientist; both are affiliated with the Program in Science, Technology, and Society at M.I.T. and both hold coveted MacArthur Prize Fellowships.

Norman Geschwind, 1926-1984

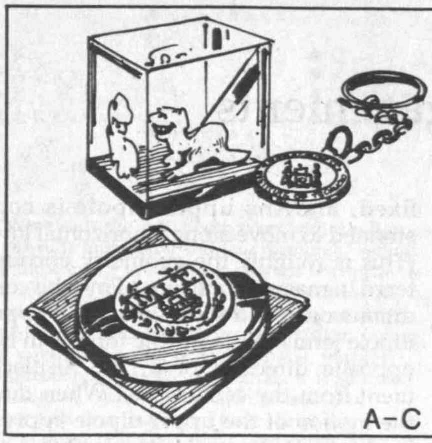
Norman Geschwind, professor of psychology who also held appointments in the Harvard-M.I.T. Division of Health Sciences and Technology and as James Jackson Putnam Professor of Neurology at Harvard Medical School, died of sudden cardiac arrest at Beth Israel Hospital, Boston, on November 4; he was 58.

Dr. Geschwind joined the M.I.T. faculty in 1978 as a world authority on clincial neurology; his research focussed on the relationship between brain anatomy and behavior, and he was a major force in rethinking the functional architecture of the brain and, in his words, the "specialized talents" of its two hemispheres. Dr. Geschwind was associated with Boston City Hospital and Boston University Medical School before becoming chief of neurology at Beth Israel Hospital in 1975; he was a graduate of Harvard and Harvard Medical School.

Deceased

Edward D. Merrill, '09; October 28, 1984; c/o Mrs. Richard Pilkinton, 3104 Hawthorne St. NW, Washington, D.C.
Mrs. Leonard W. Pritchett, '09; August 4, 1983.
Herman E. Morse, '15; September 17, 1984; 329 Overwood Rd., Akron, Ohio.
Stanley L. Chisholm, '17; 1983; 3091 Cowley Way No. 5, San Diego, Calif.
Elbert H. Bancker, '18; July 5, 1984; 6065 S Verde Trail, G-223, Boca Raton, Fla.
Albert F. Murray, '18; October 8, 1984; 4900 Hillbrook Ln. NW, Washington, D.C.
Sister St John Nepomucene, '18; 1984; Villa Julie, Valley Rd., Stevenson, Md.
Kenneth E. Pote, '18; July 29, 1984; 17 Westernview Cr., c/o Hechler, East Longmeadow, Mass.
Charles H. Watt, '18; 1984; 100 Old Billerica Rd. No. RW149, Bedford, Mass.
Joakim Lehmkuhl, '19; October 15, 1984; c/o James Herman, PO Box 449, Old Lyme, Conn.
Foster P. Doane, Jr., '20; July 16, 1984; 501 East Wisconsin Ave., Neenah, Wisc.
Augustus Sherrill Houghton, '20; October 12, 1984; 2217 Cheyenne St., Golden, Col.
Bruce M. Steele, '20; October 14, 1984; 39 Cliff St., Burlington, Vt.
Kaare Aass, '24; May 9, 1984; Forvaltning Radgivenz, Norev, Oslo, Norway.
Alvan Fisher, '24; October 7, 1984; 11 Beacon St., Natick, Mass.
Gordon W. Harvey, '24; July 7, 1984; 4712 B Robinwood Terr., Boynton Beach, Fla.
Francis E. Manley, '24; November 2, 1984; Bay Village No. 1263, 8400 Vamo Rd., Sarasota, Fla.
Walter C. Ames, '25; July 2, 1984; RT 2 Box 11, Moon, Va.
Frank W. Cole, '25; December 26, 1983; PO Box 63, Sperryville, Va.
George Colburn Myrick, '25; September 13, 1984; 166 Winne Rd., Delmar, N.Y.
Herbert P. Sontag, '25; August 18, 1984; 3280 A 39th St. S, Boca Bay, Saint Petersburg, Fla.
Russell L. Houghton, '26; November 3, 1984; 161 West 16th St., New York, N.Y.
George E. Rogers, '26; June 7, 1984; 8 Spring St., Lexington, Mass.
Leonard B. Riley, '27; September 26, 1984; 470 Hoyt St., Denver, Colo.
Alexander D. Fowler, '28; October 28, 1984; 445 Vreeland Ave. Rd 1, Boonton, N.J.
Shikao Ikehara, '28; October 10, 1984; 2-Chome-19-20 Meguro-Honcho, Meguroku, Tokyo, Japan.
Leroy H. Nothdurft, '28; November 15, 1984; 45 Hawthorne Rd., Wayne, N.J.
Raymond L. Wofford, '28; July 20, 1984; 961 La Tierra Dr., Lake San Marcos, Calif.
Gustav A. Stein, Jr., '29; May 16, 1984; c/o A. Fletcher, 2211 NE 36th St.,! o. 204, Lighthouse Pt., Fla.
Harold M. Baker, '30; September 18, 1984.
John V. Berger, '31; October 9, 1984; 267 Acoma St., Denver, Co.
Bertil A. Franson, '32; June 11, 1984; 36 Crest Rd., Lynnfield, Mass.
Herbert A. Breitstein, '33; September 17, 1984; 32 Walnut Hill Rd., Chesnut Hill, Mass.
Frederick H. Cooper, '33; May 22, 1984; 10536 Lake Gardens, Dallas, Tex.
William S. Kraybill, '34; October 17, 1984; 7205 Marilyn Ave., Albuquerque, N.M.
John A. Lowry, '35; July 1, 1984; 3805 Overdale Dr., Columbus, Ohio.
Michael E. Scalia, '40; November 10, 1984; 19 Sunset Rd., Nahant, Mass.
Howard J. Samuels, '41; October 26, 1984; 7 W 81st St., New York, N.Y.
Clarence J. Grogan, '42; March 24, 1984; PO Box 257, Madison, Va.
Edmond J. Tyberghein, '44; November 1983.
Peter V. Danckwerts, '48; October 25, 1984; The Abbey House, Abbey Rd., Cambridge, England.
Saul Levine, '49; October 18, 1984; 9910 Fernwood Rd., Bethesda, Md.
Valentine Davidson, '51; July 24, 1984; 1133 Hidden Springs Ln., Glendora, Calif.
James D. Russell, '51; March 1984; No Great Rd., Box 237, Lincoln, Mass.
Michael Humenik, Jr., '52; July 15, 1984; 17097 Cambridge Ave., Allen Park, Mich.
Hubert P. Foreman, '54, April 18, 1984; 3038 Boxwood Dr., Montgomery, Ala.
George M. Walker, '55; November 14, 1984; 602 Tallassee St., Wetumpka, Ala.
Bryan B. Brown, Jr., '56; December 5, 1980; 721 York St., Vallejo, Calif.
Lawrence H. Leonard, '58; September 22, 1984; 514 Broughton Dr., Beverly, Mass.
Stephen T. Colman, '62; October 25, 1984; 5555 S Everett, Chicago, Ill.
Jack E. Link, '83; October 19, 1984; 89 Massachusetts Ave., Arlington, Mass.

M.I.T. *Insignia*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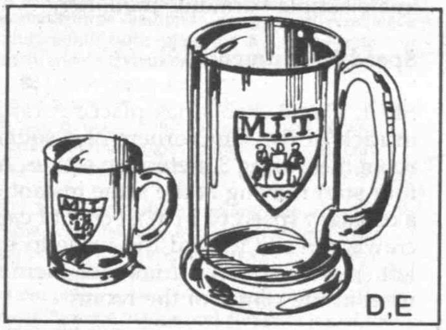
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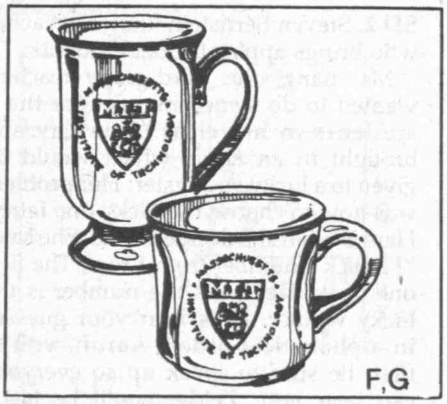
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J. BRUSHED ALUMINUM MUG with pewter insignia seal and clear glass bottom **$17**

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ALLAN J. GOTTLIEB

How to Computerize Your Engagements

As promised in the October issue, here is the current backlog of submitted problems in various classes. The shortest delay until publication is for speed problems, where I have a half-year supply. The backlogs for chess, bridge, and regular problems are each approximately one year. Some confusion has developed concerning the computer-related problems. These problems will be clearly identified when presented, and I did not intend to suggest a preference for computer calculations over mathematical analyses for regular problems. To date (November 9), I have received two problems designed as computer-related, one of which appears as **F/M 1** below. Thus, the backlog for this class is just one problem.

Finally, I must apologize to Merle Smith for misspelling his name in the October column.

Problems

F/M 1. Alfred Anderson inaugurates the computer-oriented problems with this offering; he writes:

Recently I used brute force to solve a rather interesting computer-oriented problem. Perhaps one of your readers would find a more elegant solution. Management meetings are scheduled on the second Thursday of each month, administrative conferences are the third Friday, and work units have a seminar on the first Monday. Derive an algorithm which will generate a date given the year, month, day-of-week, and ordinal week within the month. For example, if a meeting were scheduled for the third Friday of August 1984, the algorithm would return "August 17." Note that a meeting on the fifth Tuesday in March would be fine for 1983, 1985, and 1986 but not for 1984 (there are only four Tuesdays in March of 1984). In this case the algorithm could return January 0.

F/M 2. William Stein likes to deal with loosely coupled coins:

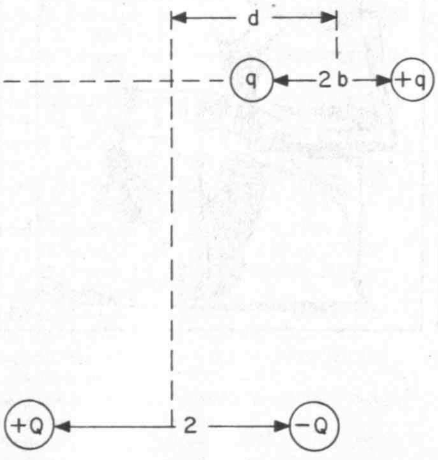
Two coins, loosely coupled, are flipped simultaneously such that if either one is heads, the other has probability 7/8 of also being heads, but if any one is tails, the other is equally likely to be either heads or tails. Find the probability of each individual coin turning up heads, and the probability of their both being heads simultaneously (or prove that the problem statement and data are inconsistent).

F/M 3. A geometry problem from Phelps Meaker:

A horizontal line of length 2a forms the common base for two isosceles triangles. On the near side the triangle is $45° - 45° - 90°$, and on the opposite side $75° - 75° - 30°$. Determine the radius of the circle tangent to all sides of the composite lanceolate figure, and locate its center.

F/M 4. Smith D. Turner $\int(dt)$ wants you to find a four-digit number whose square is an eight-digit number whose middle four digits are zero.

F/M 5. David Dreyfuss was attracted to the following problem:



Consider two dipoles with dimensions as indicated. The lower dipole is fixed, and the upper dipole is constrained to move along a horizontal line. (This is roughly the geometry encountered in magnetic stirring.) Find the conditions on h and b for which the upper dipole tends to center (the force is in the opposite direction of d, the displacement from the center line). When does the motion of the upper dipole approximate simple harmonic motion?

Speed Department

SD 1. David Evans has placed a turtle in each of the four corners of a square room measuring 3 meters on a side. All four start moving at the same instant at a constant speed of 1 cm./sec., and each crawls directly toward the turtle to the left. How long does it take for them to meet at the center of the room?

SD 2. Steven Bernstein knows a teacher who brings apples for her students:

Ms. Lang, the third-grade teacher, wanted to do something nice for the n students in her class. One day she brought in an apple which would be given to a lucky youngster. Her problem was how to choose the lucky one fairly. Here is what she decided to do: She said: "I'll pick a number from 1 to n. The first one of you to guess the number is the lucky winner. Let's hear your guesses in alphabetical order. Aaron, you're first. Be sure to speak up so everyone can hear you. Zelda, you'll be last." "Unfair!", said Aaron. "I'll have all those numbers to choose from. My chances of guessing are pretty small. Wanda, Yolanda, and Zelda will have a chance to hear everyone else's guesses so they will have a better chance of winning!" "Wait a minute," said Zelda. "I probably won't even get a chance to guess because all the other kids go first and one of them will win before it's even my turn!" Ms. Lang replied, "Children, I've thought about it and this procedure is fair. You all have the same chance of winning." Is Ms. Lang correct?

Solutions

OCT 1. What is the minimum number of high-card points needed to make a contract of 7 spades

SEND PROBLEMS, SOLUTIONS, AND COMMENTS TO ALLAN J. GOTTLIEB, '67, ASSOCIATE RESEARCH PROFESSOR AT THE COURANT INSTITUTE OF MATHEMATICAL SCIENCES, NEW YORK UNIVERSITY, 251 MERCER ST., NEW YORK, N.Y., 10012.

against the best defense?

Bob Sackheim sent us the following:

I suspect that the minimum number of high-card points needed to make a 7-spade contract is five. One possible deal would be as follows (point cards are shown; all other cards are indicated by x's, their values being immaterial):

♠ x x x x x
♥ -
♦ x x x x x x x x
♣ -

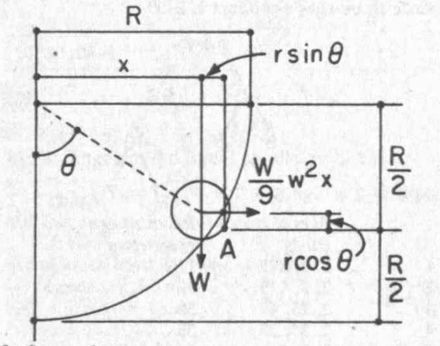
♠ K		♠ Q
♥ A Q x x		♥ K J
♦ K		♦ A Q J x
♣ A K x x x x x		♣ Q J x x x x

♠ A J x x x x
♥ x x x x x x x
♦ -
♣ -

If West leads the ♠K, South takes with the ♠A, cross-ruffs four hearts and four diamonds, setting up three hearts in his hand, plus his last spade for 13 tricks. If West leads a heart, North ruffs, leads a spade to the ♠A, then three more hearts and three more diamonds are cross-ruffed, setting up three good hearts in South's hand, plus his two remaining spades for 13 tricks. If West leads a diamond, South ruffs, plays the ♠A, then cross-ruffs four hearts and three diamonds, ending in dummy; his last spade, and either three hearts or three diamonds, are good. If West leads a club, South ruffs, plays his ♠A, cross-ruffs four hearts and four diamonds, ending in his hand; his last three hearts are good.

Also solved by Tom Harriman, Lester Steffens, Richard Boulay, Philip Dangel, Alan Robock, Warren Himmelberger, Winslow Hartford, and the proposer, Howard Sard.

OCT 2. Given a rotating hollow semi-sphere with a hole in the bottom, into which a marble is dropped, find the angular velocity required to hold the marble exactly halfway between top and bottom of the sphere. Assume the frictional coefficient between marble and sphere is μ and the radius of the sphere is R.



In figure shown,
r = radius of the marble
R = radius of the hemisphere
W = weight of the marble
w = angular velocity of the hemisphere
g = acceleration of gravity
and A is the point of contact between the marble and the spherical surface at a height R/2 above the bottom. For equilibrium in a vertical uniformly rotating plane, the moment of W about point A will equal the moment of the centrifugal inertia force $W/g \cdot w^2 x$ about the same point, Thus,
$Wr \sin\theta = W/g \cdot w^2 x \cdot r \cos\theta$, or
$w = \sqrt{g/x \cdot \tan\theta}$. Since
$\theta = \cos^{-1}(r/2)/R = 60°$,
then $\tan\theta = \sqrt{3}$. Also,
$x = (R - r)\sin\theta = \sqrt{3}/2 \cdot (R - r)$.
Substituting x and tan θ into equation (1) yields
$w = \sqrt{2g/(R - r)}$ rads./sec., the required angular velocity. If the intent of the problem was to have the center of the marble halfway above the bottom, we would have
$\cos\theta = R/[2(R - r)]$ and
$\sin\theta = x/(R - r)$. Hence, for this condition, the angular velocity from (1) would be:
$w = \sqrt{2g/R}$ rads./sec.

Also solved by Matthew Fountain.

OCT 3. In the Illinois Lottery Lotto game, the player chooses six different integers from 1 to 40. If the six match, in any order, the six different integers drawn by the lottery, the player wins the grand prize jackpot which starts at $1 million and grows weekly until won. Multiple winners split the pot equally. For each $1 bet, the player must pick two, presumably different, sets of six integers. Considering the grand prize alone, under what conditions would it pay, on the average, to play this game? In the game week ending June 18, 1983, 78 people matched all six winning integers and split the jackpot. Estimate the odds of this outcome, given that 2 million people bought $1 tickets that week.

There are $\binom{40}{6}$ or 3,838,380 possible combinations which might be chosen. It will prove highly convenient to round this off to 4×10^6. The expectation for a lottery participant would be easy to compute, if we didn't have to worry about multiple winners. Choosing 2 out of 4,000,000 combinations, someone would have a 1/2,000,000th chance of winning. The prize would have to exceed $2 million before it would pay, on the average, to play the game. But, in fact, the prize would have to be significantly higher than this, because there is a good chance of multiple winners. The probability that a winner will have to share his prize is only 1/e, as can easily be shown. There are, according to information given later in the problem, 2,000,000 people playing the game. That is, 4,000,000 combinations are selected. Since there are 4,000,000 *possible* combinations, the probability that any given selection does not match the winner (*assuming that each selection is equally likely*) is
$[(4 \times 10^6) - 1]/(4 \times 10^6)$.
The probability that all the other selections don't match the winner is
$([(4 \times 10^6) - 1]/4 \times 10^6)^{4 \times 10^6}$
This is very close to 1/e since, as is familiar from calculus,
$\lim [(n - 1)/n]^n = 1/e$.
So there is a probability of $1 - 1/e$ that there will be additional winners. We will need to know the probabilities of specific numbers of additional winners, and these can be obtained from the Poisson formula:
$\mu^k/k! \cdot e^{-\mu}$.
This gives the probability of k additional winners, where μ is the average number of winners. In the present case μ is 1, since there are 2,000,000 participants, each with a 1/2,000,000th chance of success. The following table may be compiled:

	Probability
No additional winner	.37 (= 1/e)
One additional winner	.37
Two additional winners	.18
Three additional winners	.06
Four additional winners	.01
Five or more winners	negligible

What this indicates is that a winner has a .37 chance of getting all the money, a .37 chance of getting half the money, etc. What the winner could expect would be, roughly,
$.34 + .37/2 + .18/3 + .06/4 + .01/5 = .63$
of the prize money. In order for the lottery to be a good bet, 63/100 times 1/2,000,000 times the prize money would have to exceed $1. That is, the prize money would have to exceed $3.17 million.

To determine the probability of the June 18, 1983, result, we again make use of the Poisson formula, with k = 78. This gives the probability that 78 people will have a given winning combination. Since 78! is on the order of 10^{115}, this is an extremely low probability. An event this unlikely could not, practically speaking, have happened. But it did happen. Therefore, something has gone wrong in the preceding calculations.

The problem lies in the assumption that each combination is equally likely to be picked by lottery participants. In fact, people do not choose

numbers at random. They choose numbers which have some significance. Often this is a strictly individual significance (one's age, a date of the month with special meaning, etc.). But the choices are sometimes on the basis of a more general significance. Some numbers (e.g., 7 and, to a lesser extent, 3) are believed to be lucky. These and related numbers, such as 21, 33, and 37, will be heavily over-represented in the selections. By a reverse psychology, 13 might also be popular.

What *were* the winning numbers for June 18, 1983? This can be looked up in daily papers of the region for June 19. When I did look this up, I had some idea, based on the considerations in the last paragraph, of what I might be seeing. But, even so, I could hardly believe my eyes. The winning combination was: 7, 13, 14, 21, 28 and 35. It would be difficult to imagine a group more appealing to the believer in lucky numbers! Here we have all the products of 7 between 1 and 40, with 13 thrown in for good measure.

So the answer to the question "What was the likelihood of the June 18, 1983, result?" is now apparent, though it doesn't lend itself to exact quantification. It was *quite* remarkable (having a probability of $1/(4 \times 10^6)$ that that particular combination was the winner. It was *not at all* remarkable that 78 people chose it. The probability of the complex event (that number winning *and* being chosen by 78) is not much less than $1/(4 \times 10^6)$.

Let's consider the more general question of there being *some* result involving a very large number (say 50 or more) of winners. I am inclined to think that this is not extraordinarily unlikely. Take the following as a list (obviously not exhaustive or definitive) of lucky numbers between 1 and 40: 3, 7, 11, 13, 14, 21, 22, 28, 33, 35, 37. There are $\binom{11}{6} = 462$ combinations of these numbers which might be selected. Given that the total of possibilities is 4×10^6, it's not likely that any of these will again be selected in the foreseeable lifespan of the lottery. But consider the combinations of five of these numbers with some other number selected for its significance to an individual. There are $\binom{11}{5} \times 29$ (about 14,400) of these combinations. The chance that one of them will be a winner is roughly .004 (1 in 250). So one of these should come up about every five years, and when it does there may well be a lot of winners. Probably not as many as 78, for these combinations don't have the unique appeal of that other one, but 50 would not seem too unreasonable for some of these combinations.

It's now quite clear that my earlier calculation of what percentage of the prize a lottery player might expect to collect can only be interpreted as an average. What a particular player can expect will vary in relation to the numbers that are selected. If he picks two of the supposedly lucky combinations, his winnings may have to be shared with 50 others. If the grand prize is at the $1 million level, each winner's share is slightly less than $20,000. Recalling that there is still just a 1/2,000,000th chance of winning, this works out to an expectation of less than 1¢.

If you deliberately choose nothing but "ordinary" numbers, your expectation is somewhat improved beyond the level I gave earlier. Let's try a quite arbitrary assumption, in order to make the discussion more concrete. Suppose half of the lottery entrants make use (consciously) of one or more of the "lucky" numbers in picking their combinations. The other half choose their numbers on the basis of considerations peculiar to themselves, so that these selections are, in the aggregate, random. If you deliberately choose only "ordinary" numbers, then you are competing only with the second group. There is no possibility that you will have to share your prize with anyone in the first group. Using the Poisson formula, we can compute a table of probabilities for this situation, similar to the table given earlier. But now μ is just 0.5. We have, on the supposition that you win:

	Probability
No other winners	.61
One other winner	.30
Two other winners	.08
Three other winners	.01

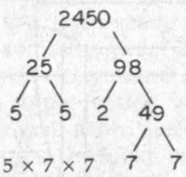
You would stand to receive .61 + .30/2 + .08/3 + .01/4, or about .79 of the prize. In the case where the prize is $1 million, this works out to an expectation of 40¢ (compared to the 1¢ expectation enjoyed by the other contestant). But note that under any circumstances, the prize must be significantly above $2 million before the lottery becomes a good bet.

Also solved by Frank Carbin, Warren Himmelberger, Matthew Fountain, and the proposer, Jonathan Hardis, who sent us a particularly complete solution. Mr. Hardis seems to be quite an authority on the Illinois lottery. Since he has a Chicago address, one might conjecture that some of his knowledge comes from empirical study.

OCT 4. An associate research professor walks into his office one morning and says to his secretary, "I had three dinner guests last night. The product of their ages was 2450. The sum of their ages was twice your age. Can you tell me their three ages?" Ten minutes later his secretary came to him and said that the problem could not be solved. He said, "You are right. I will now tell you that I was the oldest one there." The secretary was then able to tell him the ages of the three dinner guests. What are the ages of the dinner guests, her age, and the professor's age?

The following solution is from Tom Gallahan: The first thing to do is make a list of the possible combinations of ages. Once the secretary has done this he/she can eliminate the ones that do not add up to twice his/her age. If there were only one set of ages that fit the criteria it would be the answer. This is not the case because he/she cannot solve the problem. There must be more than one choice. The fact that the professor is the oldest one there must distinguish between the possible choices so that the secretary can solve the problem.

In making a list it helps to make a factor tree, since three ages's product is 2450.



$2450 = 2 \times 5 \times 5 \times 7 \times 7$

	Ages of guests	Resulting age of secretary
1	2, 5, 245	126
2	2, 7, 175	92
3	2, 25, 49	38
4	2, 35, 35	36
5	5, 5, 98	54
6	5, 7, 70	41
7	5, 10, 49	32
8	5, 14, 35	27
9	7, 7, 50	32
10	7, 10, 35	26
11	7, 14, 25	23

You must also realize that one or two of the guests may be one year old:

12	1, 25, 98	62
13	1, 35, 70	53
14	1, 49, 50	50
15	1, 1, 2450	1226

None of the guests may be 0 years old because the product of the guests' ages in that case will always be 0.

For ease of explanation I have numbered the sets of ages. All of the resulting secretary's ages are distinct except 7 and 9. One of these must be the correct answer; thus we now know that the secretary is 32 years old. In case 7 the professor must be 50 years old or older to be the oldest one there. In case 9 he must be 51 or older. If the professor is 51 or older the secretary can't choose between the sets. The professor must be 50 years

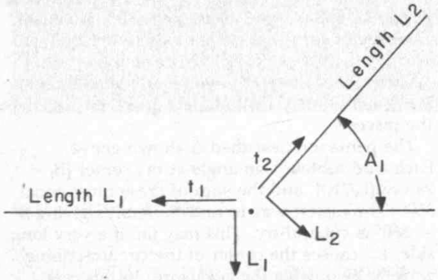
old and 7 must be the correct set. Logically we could have eliminated 1, 2, and 15 but this is unnecessary.

Also solved by Michael Jung, Matthew Fountain, David Griesedieck, Tom Harriman, Naomi Markovitz, Richard Boulay, Fernando Saldanha, Jerry Sheldon, Clarence Cantor, Steve Feldman, Dennis Loring, Ronald Raines, James Michelman, Avi Ornstein, Tso Yee Fan, John Rosendahl, Raymond Gaillard, E.R. Foster, Danny Mintz, Roy Levitch, Miriam Nadel, Tom Lydon, Myles Friedman, Pierre Heftler, Frank Carbin, Winslow Hartford, Harry Zaremba, and the proposer, Merle Smith.

OCT 5. Given an irregular polygon of n sides, in which sequence should the sides be arranged and how should the corner angles be determined to give the greatest area?

The following solution is from the proposer, Irving Hopkins:

Consider that the polygon is the horizontal cross-section of a vertical open-topped water standpide, the rectangular sides of which are hinged together along their vertical edges. There is no friction in the hinges, and the lower end of the vessel rests in a friction-free manner on a horizontal plate with no leakage of water. Gravity causes the water to fall until the sides have moved to what must be the enclosure of maximum area. When movement of the water has ceased, the pressure at any depth is uniform in all directions. The stress in the sides depends on the depth, but the geometry does not vary with the pressure. Assume a depth at which a side of width L and a suitable vertical dimension is subject to a force 2L. At the junction of L_1 and L_2 the forces are as shown, where t_1 is the tension in L_1 and t_2 that in L_2.



At the hingepin, the forces parallel to L_1 balance if

$t_1 = t_2\cos A_1 + L_2\sin A_1$ (1)

and the perpendicular forces if

$L_1 + L_2\cos A_1 = t_2\sin A_1$ (2)

Going on to other corners, we have:

$t_2 = t_3\cos A_2 + L_3\sin A_2$ (3)

$L_2 + L_3\cos A_2 = t_3\sin A_2$ (4)

. . . . .

$t_n = t_1\cos A_n + L_1\sin A_n$ $(2n - 1)$

$L_n + L_1\cos A_n = t_1\sin A_n$. (n)

From the even-numbered equations above:

$t_1 = (L_n + L_1\cos A_n)/\sin A_n$

$t_2 = (L_1 + L_2\cos A_1)/\sin A_1$

$t_n = (L_{n-1} + L_n\cos A_n - 1)/\sin A_1$.

Substituting these values of t in the odd-numbered equations, we get:

$(L_1\cos A_n + L_n)/\sin A_n = (L_1\cos A_1 + L_2)/\sin A_1$ (I)

$(L_2\cos A_1 + L_1)/\sin A_1 = (L_2\cos A_2 + L_3)/\sin A_2$ (II)

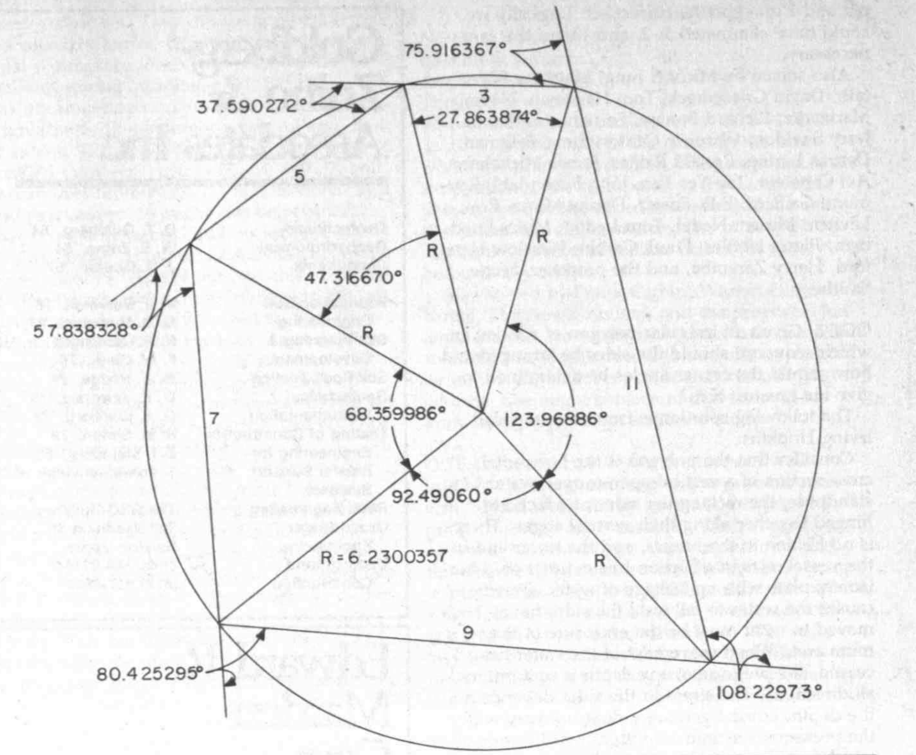
. . . . .

$(L_n\cos A_{n-1} + L_{n-1})/\sin A_{n-1} = (L_n\cos A_n + L_1)/\sin A_n$. (III)

We now have n equations from which to find the values of angles A_1 to A_n. But there is one more requirement: the sum of A_1 to A_n must be 360°. Assume a value for A_1 and let Q equal the left-hand side of (II). Square both sides of (II), which becomes

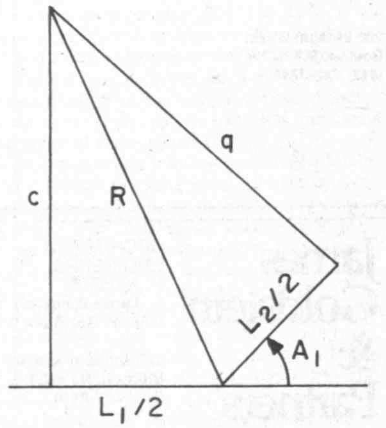
$\cos^2 A_2(L_2^2 + Q^2) + 2L_2L_3\cos A_2 + (L_3^2 - Q^2) = O$.

This is a quadratic equation in $\cos A_2$ from which A_2 may be found, and so on. For a pentagon with sides 3, 5, 7, 9 and 11 in length the angles were found to be



A_1 37.590°
A_2 57.838°
A_3 80.425°
A_4 108.230°
A_5 75.916°

Could such polygons be circumscribed by circles? If so, each side of the polygon is a chord of the circle, whose center must lie at the point of intersection of the perpendicular bisectors of the chords. Consider two adjacent sides of the polygons, say L_1 and L_2, with angle A_1.



Taking
$c = (L_2/2)\sin A_1 + q\cos A$, and horizontally
$L_1/2 = q\sin A_1 - (L_2/2)\cos A_1$.
From these equations we find that
$c = [L_2/2 + (L_1/2)\cos A_1]/\sin A_1$,
and the radius R_{12} determined from sides L_1 and L_2 is
$R_{12} = (c^2 + (L_1/2)^2)^{1/2}$
$= [(L_2/2) + (L_1/2)\cos A_1]^2/[\sin^2 A_1 + (L_1/2)^2]^{1/2}$
which boils down to
$4R_{12}^2 = (L_1^2 + 2L_1L_2\cos A_1 + L_2^2)/\sin^2 A_1$ (IV)
The existence of a circumscribing circle depends on $R_{12} = R_{23} = \ldots R_{n1}$. By analogy with (IV),
$4R_{23}^2 = (L_2^2 + 2L_2L_3\cos A_2 + L_3^2)/\sin^2 A_2$ (V)
Squaring both sides of (II), we get
$(L_1^2 + 2L_1L_2\cos A_1 + L_2^2\cos^2 A_1)/\sin^2 A_1 = (L_3^2 + 2L_2L_3\cos A_2 + L_2^2\cos^2 A_2)/\sin^2 A_2$. (VI)
Subtracting the left side of (VI) from the right side of (IV), and the right side of (VI) from the right side of (V), we get
$L_2^2(1 - \cos^2 A_1)/\sin^2 A_1 = L_2^2$, and
$L_2^2(1 - \cos^2 A_2)/\sin^2 A_2 = L_2^2$.
The right sides of (IV) and (V) are therefore equal; hence R_{12} and R_{23} and all the other R's are equal. The area of each triangle is easily found by Area $= (L/2)[R^2 - (L/2)^2]^{1/2}$. The sequence in which the sides are arranged is immaterial, equivalent to carelessly cutting a pie and then shuffling the pieces.

The pentagon described is shown above. Each side subtends an angle at the center [$B_i = 2\arcsin(L_i/2R)$], and the sum of these must equal 360°. The easiest way to find the radius giving B = 360° is cut-and-try. This may fail if a very long side, L_n, causes the center of the circumscribing circle to be outside the enclosure. In this case, solve for

$$\sum_{i=1}^{n-1} B_i = B_n$$

Also solved by Matthew Fountain, Tom Harriman, Winslow Hartford, and Harry Zaremba.

Better Late Than Never

M/J 4. Andre Schmitz found a simpler way to present the solution.

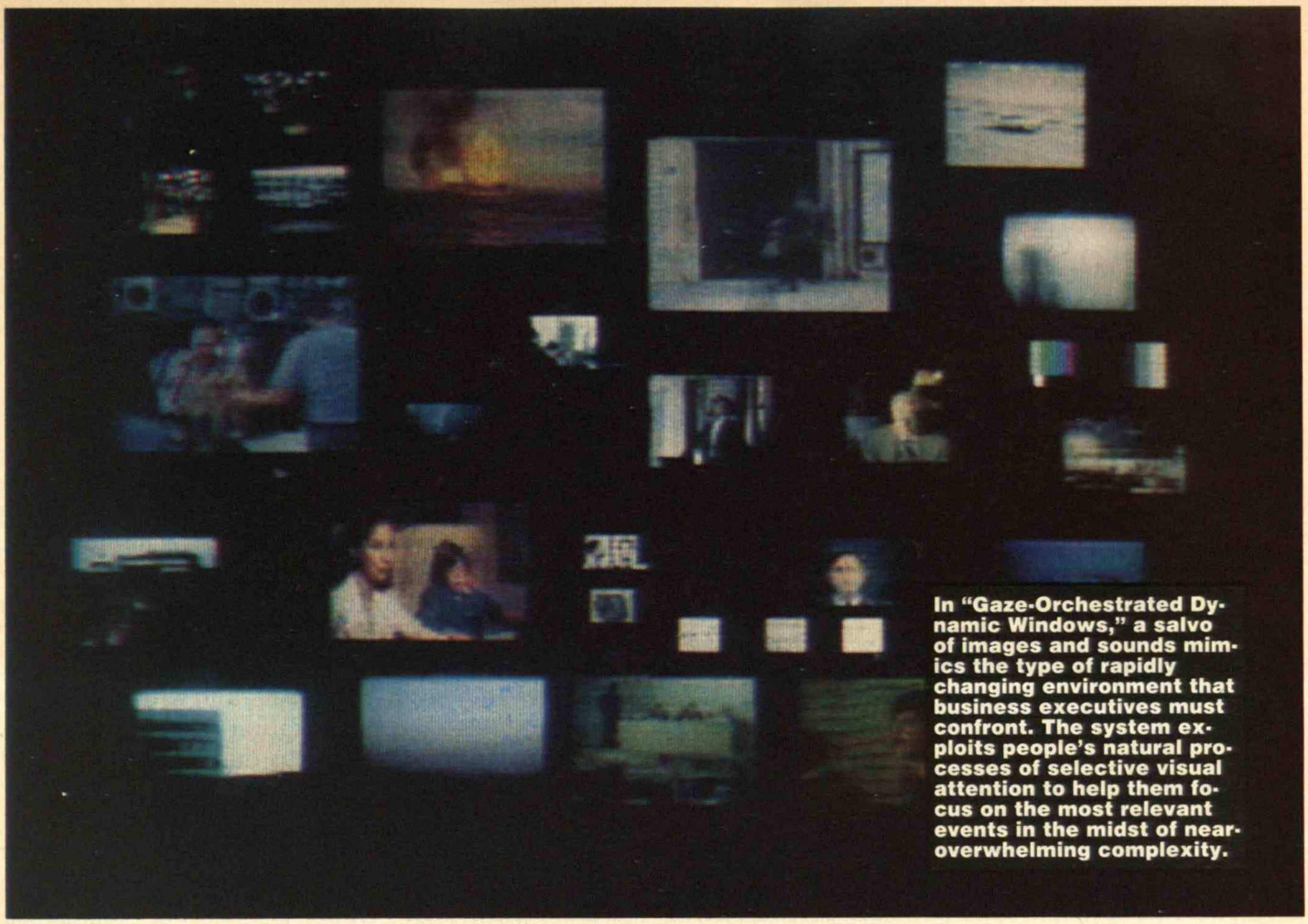
A/S 4. Dick Swenson has responded.

Proposers' Solutions to Speed Problems

SD 1. Five minutes. Since the turtles move at right angles to each other, an approached turtle's motion does not contribute to the distance the approaching turtle must travel.

SD 2. Yes, Ms. Lang is correct. Each child has probability 1/n of winning. Aaron's chance is 1/n because he has n numbers to choose from. The k-th child will win if each of the k − 1 children that went before him/her guessed incorrectly and the k-th guesses correctly. The probability of this happening is:
$[(n - 1)/n][(n - 2)/(n - 1)] \ldots (n - k + 1)/(n - k + 2)[1/(n - k + 1)] = 1/n$.

Notice that in order for this to work it is necessary for each guess to be heard by the children to follow. In this way the disadvantage of going near the end is exactly compensated by a narrowing down of choices.



In "Gaze-Orchestrated Dynamic Windows," a salvo of images and sounds mimics the type of rapidly changing environment that business executives must confront. The system exploits people's natural processes of selective visual attention to help them focus on the most relevant events in the midst of near-overwhelming complexity.

Give-and-Take

This kind of interchange between human and computer is a process of mutual self-disclosure. The computer is disclosing itself—or, more specifically, its contents—on the basis of the user's disclosing of himself or herself explicitly in speech and gesture and implicitly by eye movements. It is an ongoing two-way process.

What drives this conversation? What keeps it going and gives it direction? It is primarily the *curiosity* of the user as it interacts with the built-in *reactivity* of the system. For example, psychologists have shown that people are attracted to things that are visually rich and complex. People are also driven by so-called epistemic curiosity: we want to know the why and what of things. In its response to these "simple" levels of curiosity, the system obligingly tries to follow whatever leads its users give. The computer's "personality" is that of the convivial yet reserved person: it responds in a lively way but doesn't push itself on the user.

The system can readily sense the difference between a politely curious inquirer and a "serious" one—the difference, for example, between the tourist who strolls through Westminster Abbey taking it all in and the scholar who studies it. Both might spend the same time looking, but their ways of observing provide a clue to how organized and comprehensive a guide's exposition must be—technical for the scholar, lucid but light for the tourist.

When a user has an even more compelling reason to communicate with the system, the computer can respond in kind. For instance, if you are a graduate student who must know all about colonial architecture in New England by final exams next Wednesday, you can instill motivation in the system by asking it, "Tell me about colonial architecture." Now the computer goes directly into a kind of superordinate "teaching" mode, in sharp contrast to its previously relaxed, reserved posture. The system may go slowly now and then to let you digest information when it senses that your rate of uptake has faltered. But it assumes more responsibility for shaping the exchange than in the more leisurely mode. All the while, whether the overall mode is relaxed or purposeful, the moment-to-moment conversational initiative drifts to and fro between human and computer, much as the "attack" passes back and forth between two fencers. Thus, the actions of the user and the system are mutually determined, either party by turn driving or being driven.

The hardest job will be fostering a view of the computer interface as a comfortable place where people and machines truly "keep company."

Users' sophistication—their style of looking and the questions they ask—can also help determine how the computer will respond. For instance, novices and expert chess players look at board positions differently. And of two people interested in antiques, one may have a "trained eye" for detecting the fine points of a collectible while the other examines the item in a less disciplined way. Such differences in looking style, though subtle, can enable a computer to infer what should be shown and said next.

Keeping Company

In person-to-person conversation, we speak not to some disembodied spirit but to someone right before us. One of the benefits of this direct presence is that we can look the person in the eye—for example, we can shift our gaze from an object under discussion to the eyes of the person with whom we're speaking. Beyond the sense of engagement this creates, eye contact can signal that we wish to shift the discourse to a personal level: to talk "to" the person rather than "with" them about external matters. Given that conversationality is a positive value in human-computer communications, how might we establish the ability to look the machine "in the eye"?

Patrick Purcell and some of his students at M.I.T. have been experimenting with a kind of computer "persona." Next to the Media Room's display screen is a video monitor that bears the face of a person—in this case, Professor Purcell himself. When you speak to the system—for example, to command it to display the art and architecture slides stored on its videodisc—this image speaks back to you. You ask: "I'd like to see some examples of Romanesque." The face on the monitor responds with synthesized speech, "Early or late?" The lips on the image are synchronized to the phonetics of the synthesized speech in a convincingly lifelike way.

This exercise was originally done somewhat tongue-in-cheek, with the modest goal of providing a more cordial, congenial channel for output messages than the line of print or the disembodied voice. The persona doesn't—yet—track the user's eyes and thus can't tell whether he or she is paying attention. With eye-tracking powers added, the persona could become a specific spot for the user to look at to establish "eye contact" with the machine.

Many of these technologies to support friendlier and richer human-computer interactions already exist, at varying levels of refinement. Devices that recognize and synthesize speech have improved markedly in recent years. Reliable touch-sensitive screens that enable users to point at data on display are on the market. Body-sensing equipment for capturing various levels of gesture is developing apace. For example, researchers in our laboratory are working on a glove that will allow the computer to discern a user's hand and finger movements. What has not existed is the appreciation of such technologies as essential parts of a computer's instrumentation.

Eye tracking offers a good example. Unobtrusive tracking systems that can be situated as much as six feet from the user have been available for several years. But they cost about $100,000, which prohibits them from serious consideration as system components. Part of the high cost is due to the proverbial chicken-and-egg dilemma. The systems are currently sold one at a time to research laboratories as measurement tools, not in large quantities to become part of well-equipped computer systems. Growing demand and high-volume production would help lower costs. But the fact that eye tracking can become a system component has not yet really struck home. There is a vague sense that tracking may be useful, but no real conviction.

This situation could change with new developments in digital cameras, microprocessors, and tracking technology. As tracking systems become more compact, they will become embedded in terminals as an integral part of new systems. In the long run, the price of a tabletop or personal computer will less and less reflect the memory and processing elements. Rather, it will reflect the costs of the electromechanical accoutrements that capture the user's intentions.

More difficult than developing the hardware for capturing multiple human modes of conversation, however, will be creating the machine intelligence to interpret human outputs and map appropriate responses. This effort will involve computer science, psychology, linguistics, artificial intelligence, and cognitive science—with scientists from all disciplines contributing to the necessary insights and inventions.

But hardest of all will be fostering a view of the computer interface as a comfortable place where people and machines truly "keep company." The world of computers outside the home—where the largest number of computer consumers still resides—contains two classes of users. There are those people

who actually operate computers, and there are those who decide whether to adopt a particular kind of computer. The latter users are usually indifferent to the subjective experience of those who actually interact with machines.

Most organizations operate according to the ethos that those lower in the hierarchy should not be too comfortable, and that the tools provided for them should be "cost-effective." If one tool is a computer that is excruciating to use, so much the worse for the employee. Unless they are computer buffs, people higher up in an organization usually avoid computers and hence do not understand the feelings of frustration and lack of control they can engender.

The world of home computers is different. People who buy those machines are normally the users, and they put a high stake on their subjective experience at the interface. For them, the flavor of "keeping company" *is* the bottom line. Yet the loudly trumpeted home-computer revolution seems to have stalled. People perceive word-processing and spreadsheets as helpful and games as entertaining babysitters for the kids, and that's about all. Only when home computers provide a real help—and good company—will the true revolution begin. Then, inexorably, people in the workplace will come to expect and even demand the kind of conviviality they are accustomed to at home. That vision is seductive.

RICHARD A. BOLT is a principal research scientist in M.I.T.'s Media Laboratory, where he is acting head of its Human-Machine Interface Group. He is the author of The Human Interface, *(Lifetime Learning Publications, a subsidiary of Van Nostrand Reinhold, 1984).*

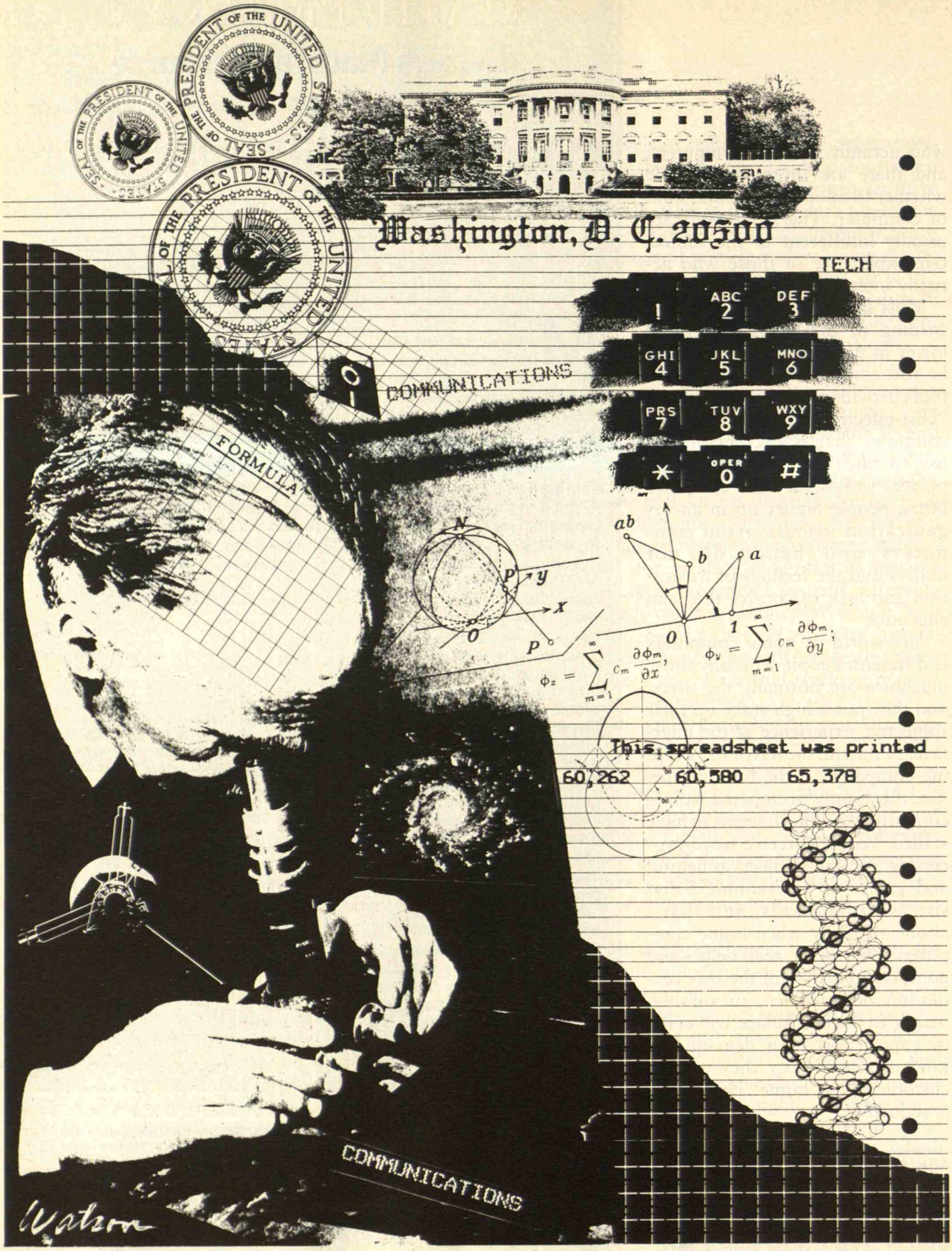


ILLUSTRATION: KAREN WATSON

Since 1981, U.S. science policy has emphasized the contributions of basic research to industrial competitiveness. That major theme, the president's science advisor asserts, will be refined during the second Reagan administration.

Science and Technology Policy: The Next Four Years

BY GEORGE A. KEYWORTH II

FOUR years ago the Reagan administration, as part of a broad reevaluation of the relationship between government and society, took a fresh look at the rationale and impacts of the federal government's large programs in support of research and development. Certainly, one driving force behind this reevaluation, which continues today, is the sheer pervasiveness of science and technology in the modern world. The rise of fierce foreign competition in both the world and domestic market means that industry rises or falls on its technological advantages.

A quarter century ago, U.S. industry had few worries about competition. The United States dominated essentially all industrial technologies, and had always been able to develop and introduce them at its own pace. Today we must use our technological resources much more aggressively. Technology and talent are virtually our only clear competitive advantages in a world where the dollar may be permanently overvalued, where foreign governments are subsidizing capital costs, and where foreign labor is often an order-of-magnitude cheaper than domestic labor. Thus, in the second Reagan administration, we intend to use our funding of R&D most effectively to guarantee that we continue to retain those two advantages.

Getting Value for Money

Industrial technology is the end-product of a multistep process of research, development, and application. Modern electronics illustrates the steps, which begin with the kind of fundamental research done in universities and federal laboratories. In this case, one strand of that research was highly theoretical work on the quantum theory of solids. Scientists and engineers then applied those basic concepts in a device to switch electric currents; that became the transistor. Finally, the crude early transistor was refined into a commercial reality that, in turn, became the basis for the industrial explosion into microcircuits applied to computers, automatic control, and a whole new world of consumer electronics. This process emphasizes the critical role of basic research in the development continuum.

Most industrial nations invest roughly comparable fractions of their GNP in the broad process of R&D. The United States will invest some $110 billion in R&D next year—more than Japan, France, West Germany, and the United Kingdom combined. That's roughly 2.7 percent of U.S. GNP—about the same as the most ambitious of our competitors, and more than many of them. So in both relative and

Reductions in funding for federal energy projects enabled the U.S. to finance its spectacular growth in basic research.

absolute terms we would appear to be in good shape to maintain our technological leadership.

However, impressive as those figures are, they may mask a serious weakness. The federal government supports nearly half of U.S. R&D—about $55 billion—to meet public needs. These include space, health, energy, and, particularly, defense, reflecting the post-World War II role of the United States in anchoring the security of the free world. In fact, we spend far more of our R&D funds than our international competitors on objectives other than strengthening industry's ability to compete. To me, that looms as the central issue in examining the U.S. relationship between government and industry. We must capture substantial long-term benefits for our industry from the $55 billion in federal R&D that can be used to strengthen U.S. competitiveness.

The key question then becomes: how much *does* that federal R&D contribute to our industrial technical strength? To get a handle on that, we have to look at a little history.

In the decades after World War II, technology spinoffs from federal R&D—particularly in defense—helped lay the foundation for some of today's most successful industries, including computers and commercial jetliners. Thus, industry was strongly stimulated by and benefited from this federal role. But the commercial market for technology has expanded tremendously in the past decade or so. Today industry, not government, is pushing hardest at technological frontiers in many areas. For example, government relies heavily on industry to provide it with state-of-the-art electronics of every kind. Similarly, the proliferation of commercial firms trying to stake out positions in the biotechnology market is transforming a field dominated by government and universities into one with strong industrial leadership.

My own discussions with industrial leaders confirm that there's been a striking decline in industry's dependence on government to stimulate the development of new commercial technology. But at the same time there's been an equally striking increase in industry's reliance on two items it can't produce for itself. One is the fundamental knowledge that ultimately drives the process of industrial innovation—tomorrow's equivalent of the quantum theory of solids. The other is the new technical talent that can use that knowledge to respond to industrial opportunities. So the more that industry has become the prime developer of new technology, the more it has become dependent on universities. Ironically, the ivory towers are emerging as the bulwarks of industrial competitiveness in the 1980s.

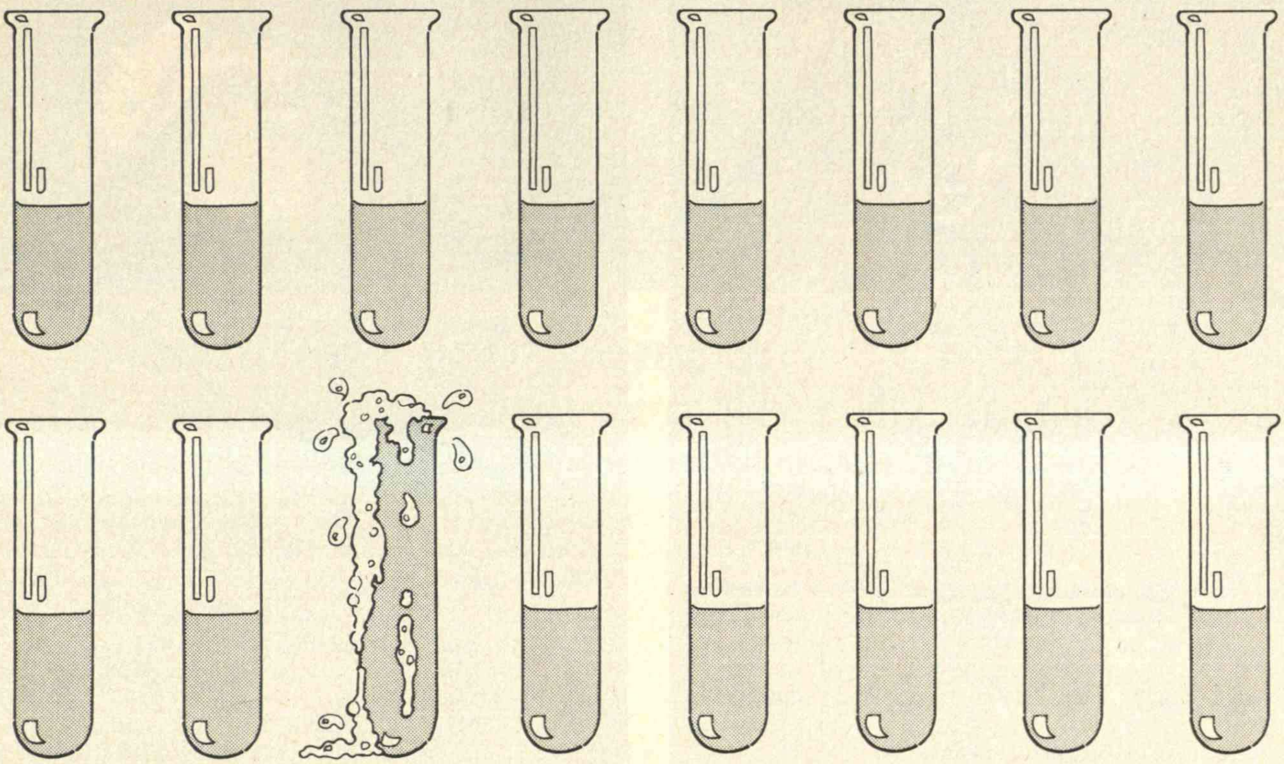
The First Four Years

The Reagan administration took decisive steps during the past four years to adjust the federal role to this new reality. With strong bipartisan congressional cooperation, the administration has beefed up support for basic research, focusing particularly on engineering and many of the physical sciences. We have also tried to build an adequate supply of people well-trained in these areas and able to apply the results in development projects chosen and funded by industry. At the same time, government has moved out of the development of technology that industry is far better qualified and motivated to do.

The most striking example of how the government can flounder in development has been in energy technology. For the billions of dollars spent on energy development in the 1970s, our biggest return was a lesson in Economics 1A—the law of supply and demand as it operates in the marketplace. Those expensive federal programs, which never did offset any significant amount of imported oil, were launched on the premise of "technology push" rather than "demand pull." However, they were overtaken by a combination of marketplace responses that held down oil prices and made most alternative sources of energy uncompetitive.

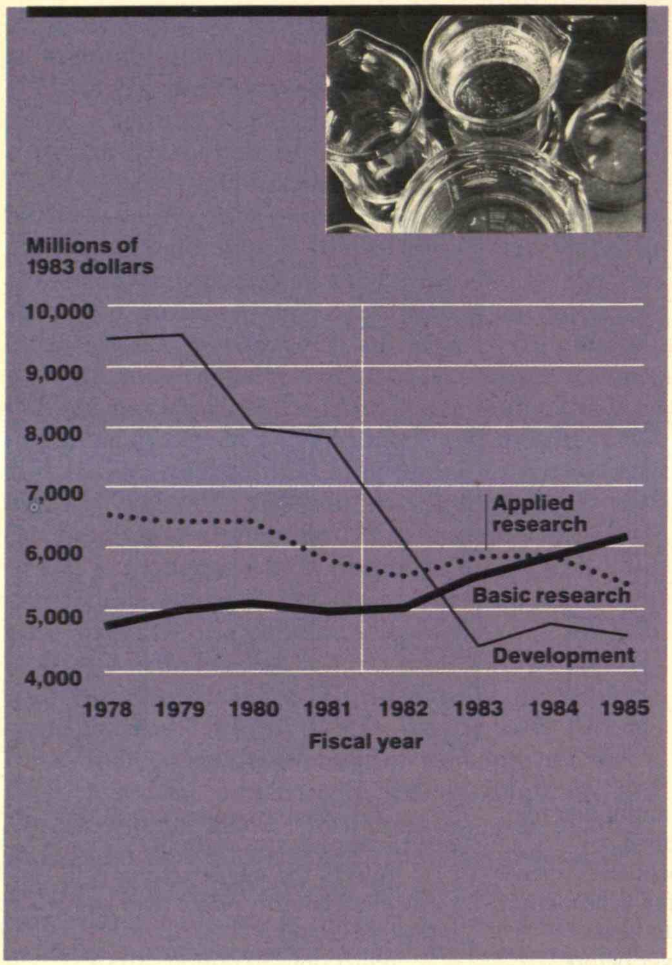
Reductions in funding for federal energy projects enabled the United States to finance its spectacular growth in basic research (*see the chart on page 48, left*). This shift in priorities is one of the clearest manifestations of the administration's science and technology policy. Basic research, for the first time ever, has climbed from the smallest fraction of nondefense R&D to the largest—from 27 percent to 38 percent. At the same time, development has dropped from the lion's share—42 percent—to the smallest, at only 27 percent. What we're saying is that basic research is clearly the federal government's responsibility, while development of new commercial technologies is best left to the private sector. Of course, that situation is totally different in defense R&D. Because the government is the only customer for defense technology, there is no comparable means of shifting development funding to the private sector.

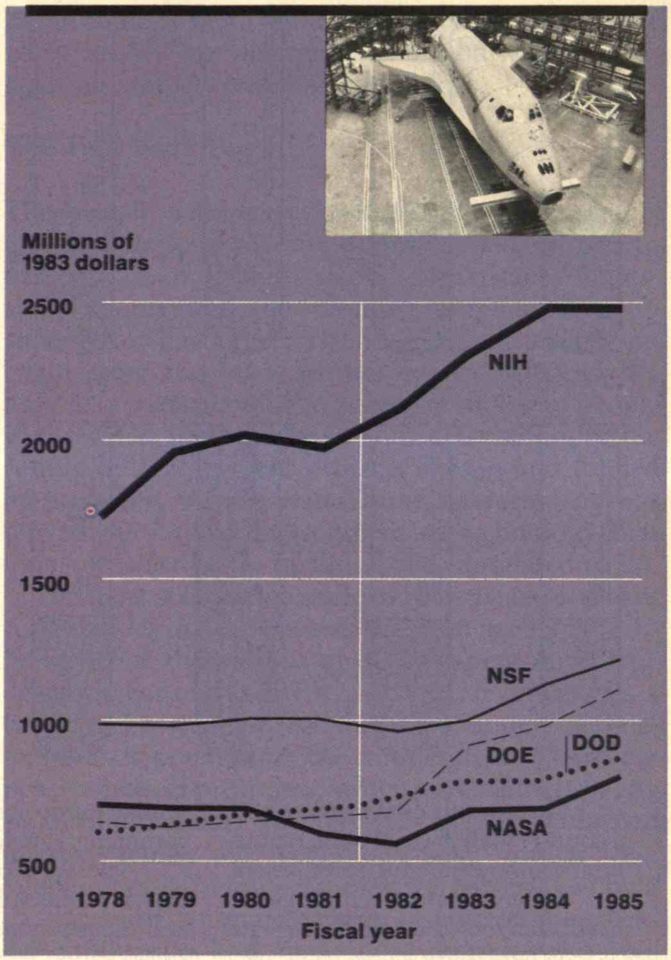
The pattern of growing support for basic research



The federal government's allocation of funds for nondefense R&D has changed drastically over the past four years. Basic research has jumped from the smallest fraction to the largest, while development has moved in the reverse direction. The vertical line between fiscal years 1981 and 1982 corresponds to the transition between administrations.

Funding for basic research among the five largest R&D agencies, which account for 90 percent of all federal support for basic research, has shown strong and consistent growth over the past four years following half a decade of either level or declining budgets in real terms. The fiscal 1985 total for basic research is almost $8 billion, up from $5 billion in 1981.





shows up across the board. The five largest R&D funding agencies—the National Aeronautics and Space Adminstration, the Department of Defense, the Department of Energy, the National Science Foundation, and the National Institutes of Health—have shown strong and consistent growth over the past four years (*see the chart above right*). Together these agencies account for about 90 percent of all federal support for basic research. Moreover, their growth follows either level or declining budgets in real terms during the five previous years. That's an important turnaround that many observers have still not grasped. Overall, the United States will spend just under $8 billion for basic research in this fiscal year, in contrast with just $5 billion spent in fiscal 1981.

Similarly, funds for basic research targeted specifically to universities and colleges have increased substantially (*see the chart on page 50*). These funds declined consistently from 1968 to 1979 and remained steady for the next two years. But since 1981, that support has grown by nearly 30 percent in real terms. Yet even though the basic research budget was expanding dramatically, we had no illusions about the necessity of spreading those increases evenly among disciplines, and certainly no illusions that we had to make sure that as many researchers as possible got their share of it. That wasn't how we did science in past four years, and it won't be in the next four.

Instead, we followed two general principles in deciding which projects to fund. We demanded that research be the best we could identify, even if that meant cutting back or eliminating ongoing projects. In light of the abundance of high-quality research projects needing support, we would have been derelict in our duty if we allowed limited resources to

Continued on page 50

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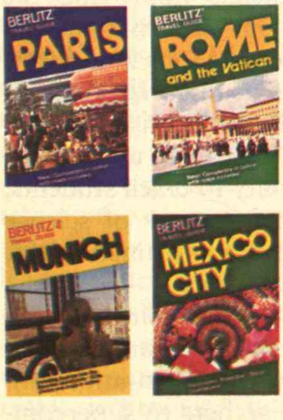

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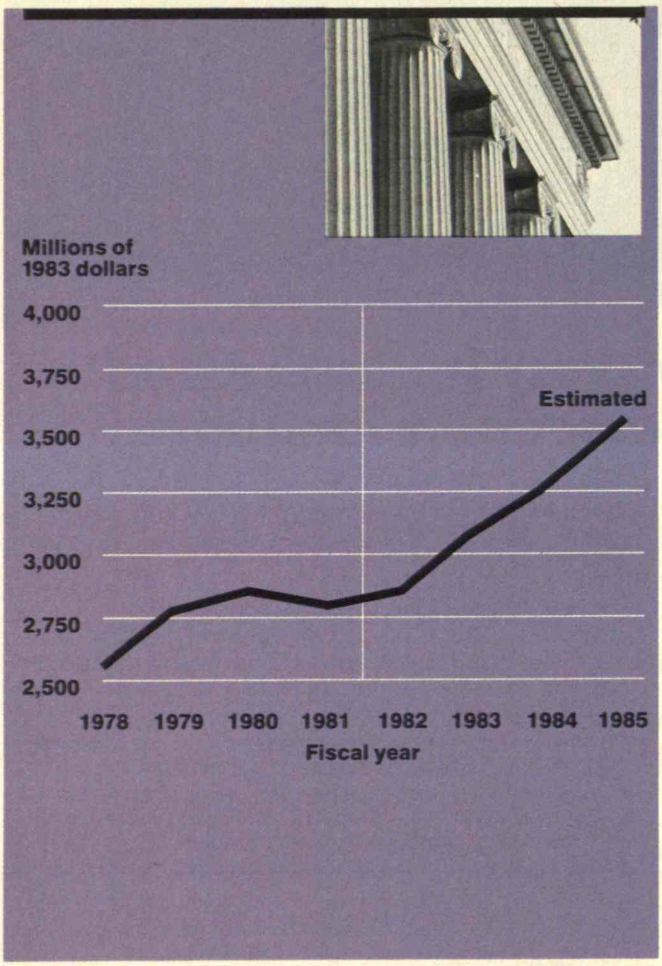
Federal funds granted specifically to universities and colleges for basic research grew by about 30 percent during the first Reagan term. That followed two years of essentially no growth and more than a decade of declining funds. The administration thinks this investment will help guarantee the nation's continuing industrial competitiveness.



be siphoned off to anything but the best. We also concentrated funding in areas most likely to benefit society, or where we could sense pure scientific excitement waiting to be turned loose.

The strong emphasis by the National Science Foundation (NSF) on engineering projects and research centers reflects this goal. Programs in supercomputers, mathematics, and materials research have also been expanded. Topics of pure scientific excitement that may benefit society include many areas of biology such as neurobiology, which we feel may be most exciting of all; particle physics, because it deals with the most fundamental questions imaginable and attracts some of our brightest young people; and space science, because our exploratory tools now allow us to take giant steps in understanding the macro environment. At the same time, we cut back support in areas where research did not offer enough intellectual excitement or industrial potential. The cuts in some of the social sciences were an example.

The decision to terminate the Isabelle Project at Brookhaven National Laboratory on Long Island was another example. Although the huge particle accelerator was years behind schedule, hundreds of millions of dollars over budget, and being overtaken by progress at other experimental facilities, there was a tacit assumption within part of the physics community that the project, once started, was guaranteed completion. However, the administration asked the high-energy physicists to determine which major facilities should receive priority. The recommendation, which the community would probably never have made without this prod, was to terminate Isabelle to ensure adequate support for more productive facilities at Fermilab outside Chicago, and at the Stanford Linear Accelerator Laboratory in Palo Alto.

Five Areas for Improvement

These considerations will continue to play the dominant role in science and technology policy in the coming four years. We will emphasize strong growth for basic research, especially at universities; programs to ensure more and better-trained technical talent; better cooperation between universities and industry; strong growth in defense R&D; and clear delineation of the responsibilities for R&D between the federal government and the private sector.

In spite of the changes that we've already made, much more remains to be done. I see five major concerns characterizing federal R&D programs in coming years.

☐ First, government must help colleges and universities attract and retain faculty of the highest quality. In simple terms, that means improving the campus climate so that ambitious scientists and engineers won't feel compelled to take jobs in industry if they want to be competitive in research. An academic brain drain is ultimately devastating for universities and industry alike, because universities simply won't have enough faculty to teach students, particularly in the fastest moving areas of science and engineering. And without newly trained talent, new industrial technology will dry up.

Of course, overall support for university research has increased. And we've taken important steps to rejuvenate funding for campus instrumentation, improve access of university researchers to supercom-

puters, and establish the presidential young-investigator program to attract and retain new faculty in critical disciplines. In addition, after a half-year review, a panel chaired by David Packard will soon make several recommendations for further action to strengthen universities for their long-term job of generating knowledge and talent to meet national needs.

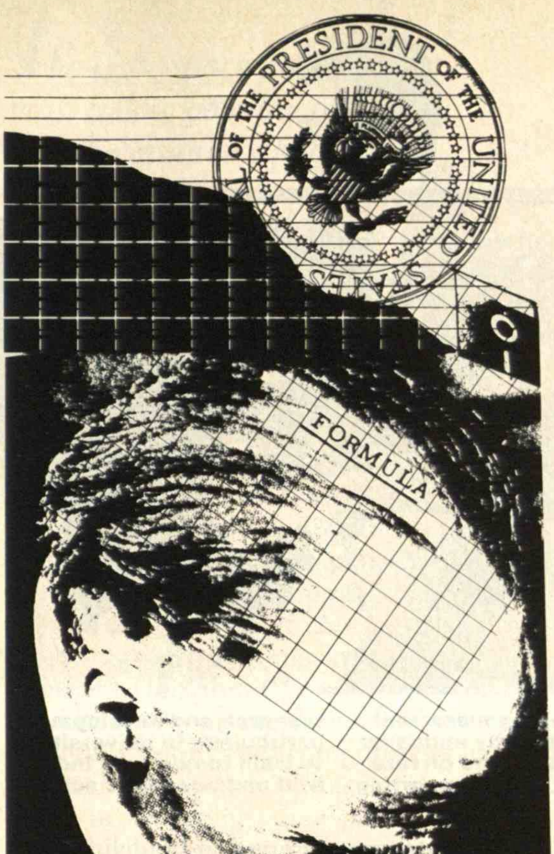
□ The second area of emphasis for government support is the generation of basic knowledge, especially in areas of particular importance to industrial competitiveness. The newly emerging biotechnology industries exist today because of decades of federal support for basic research in molecular biology. We should make sure that we're investing in comparable kinds of frontier research to fuel tomorrow's new technologies.

For example, we have expanded and redirected the biotechnology research within the Department of Agriculture. We hope the new program will attract highly qualified scientists who might not otherwise be interested in agricultural problems.

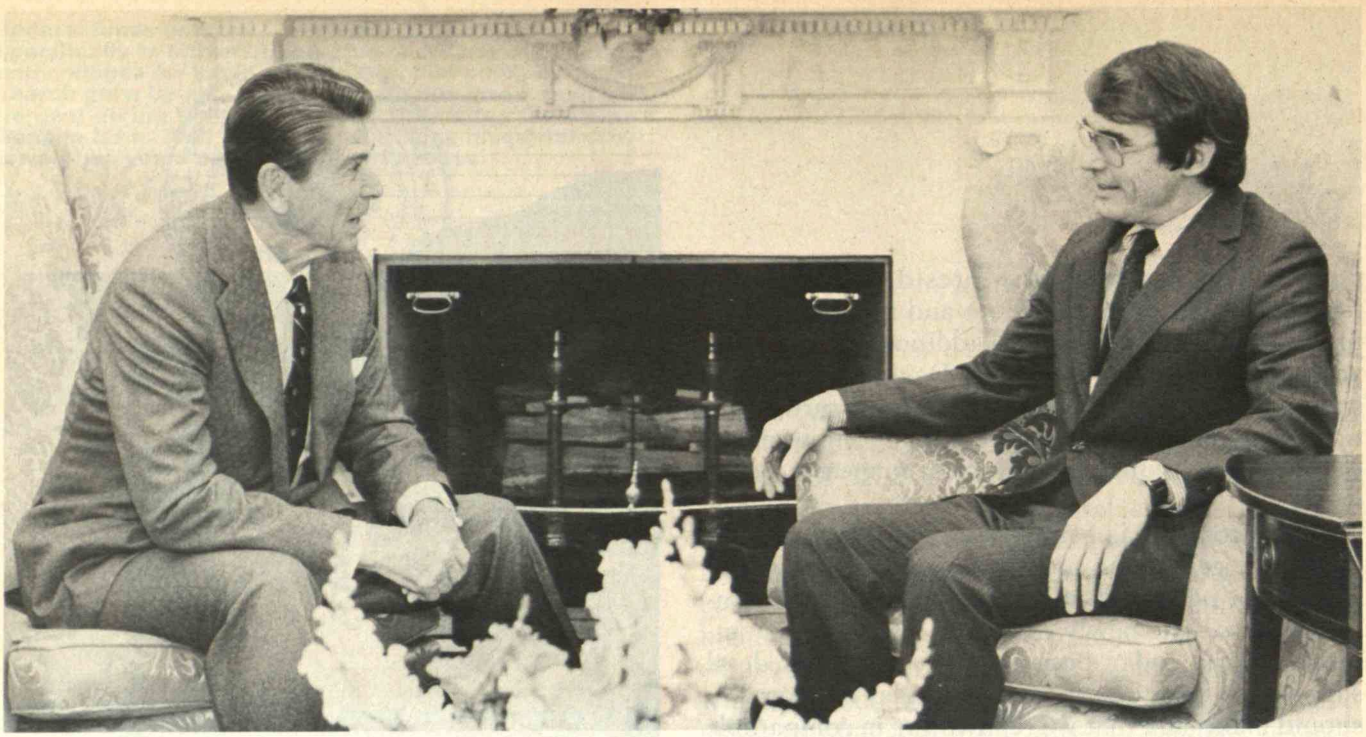
We've also made good progress in restoring support for basic research within the Department of Defense, especially at universities. At one time DOD suported much of the best university basic research. And DOD funds were largely responsible for the strength of some of today's major research universities, such as Caltech and M.I.T. That productive relationship has never really recovered from the Mansfield Amendment of the late 1960s, which prevented DOD from supporting research unless it could be directly tied to the defense mission.

We're rebuilding now because America's strength—our leverage over the Soviet Union—comes from the quality of the technology we're able to apply to defense systems. The Defense Department needs both technically trained people and broad access to knowledge about science and technology that emerge from basic research. The best means to assure the availability of both is to fund research in universities.

At the same time, we place high priority on maintaining the open communication of scientific results that has made our university system the world leader. During the past two years, there has been concern in the scientific community over a few incidents in which the government imposed restrictions on scientific papers originating in unclassified research projects. In response to those concerns,



Government must help colleges and universities attract and retain faculty of the highest quality.



"The federal government must constantly endeavor to strengthen the private economy while supporting research and development, particularly in universities, to train tomorrow's industrial and academic scientists and engineers," stated President Ronald Reagan, seen here consulting on science and technology policy with the author, presidential science advisor George A. Keyworth II.

we're in the final stages of preparing guidelines and regulations that restate and protect the basic policies of free communication. Only classified information will be restricted, and very little academic research is classified. We must distinguish between the transfer of technology to our adversaries—a serious, well-documented problem—and the flow of scientific information, which must remain essentially unimpeded.

□ Emphasis number three concerns changes we have made in government's traditional support for university research on a narrow, project-by-project basis. That method, while very successful for progress within narrow disciplinary boundaries, is severely limited in its usefulness to broad areas of industrially important topics.

I'm particularly excited about the new program in the National Science Foundation to establish cross-disciplinary centers for engineering research. There, faculty from many different departments can work together on industrial problems that none could solve on their own. And these centers will enable students to receive the kind of practical experience in solving problems just not available at universities today, and will allow industry to help determine which advances can most likely be applied to commerce.

Universities are very enthusiastic about participating in this kind of program. In the first round of proposals for these engineering centers, NSF was inundated by 142 proposals from 106 different schools, from which up to 10 will be chosen. Eventually the program will be expanded, but before that happens we need to be sure the initial centers are working well. We must also get a sense of what the balance in support should be between such interdisciplinary centers and traditional programs.

□ The fourth major responsibility of government is to find better ways to stimulate the flow of ideas, expertise, and people among the federal laboratories, universities, and industry. One-sixth of the nation's scientists and engineers are employed in federal laboratories, which have a combined annual budget of some $18 billion. These superb resources are often underutilized. We should find ways to reap substantial industrial benefit from a federal investment of that magnitude.

A year ago the White House Science Council recommended that we take better advantage of the talent in the labs and bring their missions more in line with national needs. In accordance with these recommendations, lab directors are now given more discretion in using research funds. Lab missions are also being updated and revised, and the labs are cooperating with universities and industry.

One practical result is the effort to marry the technical expertise of the labs with the needs of the steel industry. The national labs will not do the steel companies' jobs for them; this program provides access for a threatened and important domestic industry to existing taxpayer-supported technical resources. The Oak Ridge and Argonne National Labs are trying

PHOTOGRAPH: THE WHITE HOUSE

The U.S. space program must follow both the practical and the visionary paths.

to identify areas where concentrated R&D could significantly improve steelmaking efficiencies.

☐ Finally, the fifth goal of government is to be more responsive to opportunities to support emerging technologies. For example, the same federal programs that made possible the birth of today's biotechnology industry have neglected generic applied research in bioprocess engineering, despite the expenditure of billions of dollars. This research, which is necessary to facilitate development of industrial products, includes development of thermodynamic data and principles of biosensing for process and quality control. We're in real danger of letting other countries assume the industrial lead in profitable new fields of technology that American scientists have done most to establish—and that American taxpayers have underwritten.

The Promise of Space

That danger is certainly a driving reason for our determination to create improved opportunities for commercial activities in space. Under the umbrella of the National Space Strategy, signed by the president last August, we're encouraging the development of private-sector launch services and other space-based industry. Now that the space-shuttle fleet is almost fully operational and cost-effective, we must expand on our advanced space technologies by bringing in the special perspectives and market-oriented motivation of the private sector.

We hope soon to establish full-cost pricing for shuttle launch services. We expect these prices to be competitive for the kinds of highly sophisticated services that the shuttle can provide. At the same time, that price schedule should allow room for companies producing expendable launch vehicles to maneuver, and we certainly expect them to provide alternatives to both the shuttle and the Europeans' expendable Ariane system.

The U.S. space program is confronting two paths—the practical and the visionary. My firm opinion is that we have to follow both paths aggressively. Only by continuing to push at the boundaries of the vast space frontier will we be able to assure our world leadership in the more practical space technologies. We must also provide opportunities for the private sector to use its vision and creativity in addressing the enormous challenge in space. Accordingly, we're working to give federal agencies other than NASA responsibility for commercializing space activities. We intend to reserve NASA for what it does best—research and development—and to generate far greater involvement of the private sector in what it does best—serving commercial needs.

Our manned and unmanned space programs have been remarkably successful, and we need to maintain both thrusts. The repair in space of the Solar Max satellite and the retrieval of two lame communications satellites last year reminded us that the brains and dexterity of people can be crucial in space, even though automated equipment is adequate for many routine operations. Of course, one of the glories of the U.S. space program is its success in long-distance unmanned missions. We would be foolish not to take advantage of our capabilities in robotics, advanced communications, and computers as we plan for new commercial ventures. Thus, one of the challenging tasks in designing the space station now being funded is to decide which objectives should be met by humans. Industrial participation in the early planning stages for the station will ensure that it will serve industry's needs.

Challenge for the Future

The progress over the past four years has shown that we can harness basic research to achieve societal goals. But my continuing concern is that we can do more, and that our piecemeal approach fails to capture truly the potential that a $55 billion federal R&D program holds out. We want to see a better balance in federal R&D spending between essential mission requirements and the strong science and technology needed to support American technological leadership.

I believe that the science community, the universities, the administration, and Congress can make great progress in strengthening science and technology in coming years. Perhaps more than at any time in the recent past, we have a firm sense of our national needs and of the actions we have to take to build a base for long-term growth and prosperity.

GEORGE A. KEYWORTH II is science advisor to President Ronald Reagan and director of the White House Office of Science and Technology Policy. He assumed his post in 1981 after 13 years as a nuclear physicist at the Los Alamos National Laboratory. This article is an updated and expanded version of a speech given to the Council for the Advancement of Science Writing.

Charting the Way the World Works

BY DONELLA H. MEADOWS

THE *Limits to Growth,* which I wrote with several co-authors in 1972 to provide a popular account of the first global computer model, created an uproar that still echoes. Much of the problem was and remains public confusion about global models. The media depicted our model, done by the Systems Dynamics Group at M.I.T.—and the models that followed and sometimes challenged ours—as crystal balls predicting the future of almost everything and upholding wildly pessimistic or optimistic views of the world.

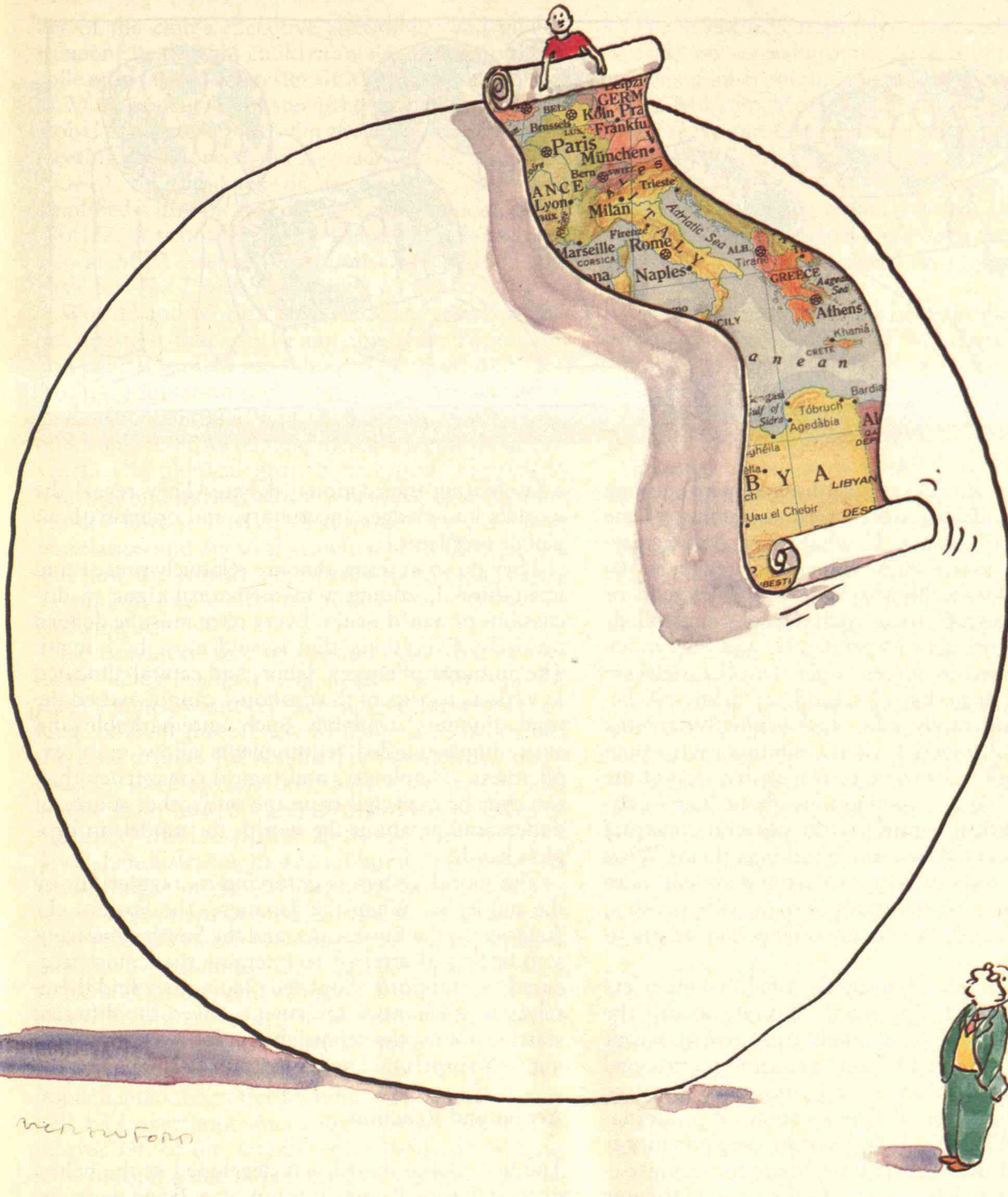
In fact, global models are not meant to predict, do not include every possible aspect of the world, and do not support either pure optimism or pure pessimism about the future. They represent mathematically assumptions about the interrelationships among global concerns such as population, industrial output, natural resources, and pollution. Global modelers investigate what might happen if policies continue along present lines, or if specific changes are instituted. For example, particular models have asked what would happen if growth continued at its present rate, if the European Common Market increased grain exports, or if infinite, free energy became available.

Since the first global model, the discipline has spread throughout the world. The Japanese have a global model. The Russians have, as far as I know, three of them. The World Bank and the United Nations have produced several models. To refute those coming from the rich countries, scientists in Latin America produced a model of their own. The U.S. Joint Chiefs of Staff commissioned a new version of a global model at a cost of $1.4 million. At a 1981 conference of the International Institute of Applied Systems Analysis (IIASA) in Vienna, representatives from 20 global-modeling groups made presentations. And no one knows how many other models exist within governments and corporations around the world.

Not surprisingly, the initial assumptions of these various global modelers are incredibly different. First, they disagree on methodology: Is it better to simulate the world as it exists, or to construct a model that optimizes it as it might be—if, for example, every government made basic human needs a first priority? Is it better to make guesses about "soft" factors such as political stability or to ignore them altogether?

Though they are made with conflicting ideologies in diverse nations, all global models basically agree on how to improve the state of the world.

ILLUSTRATIONS: MICHAEL CRAWFORD



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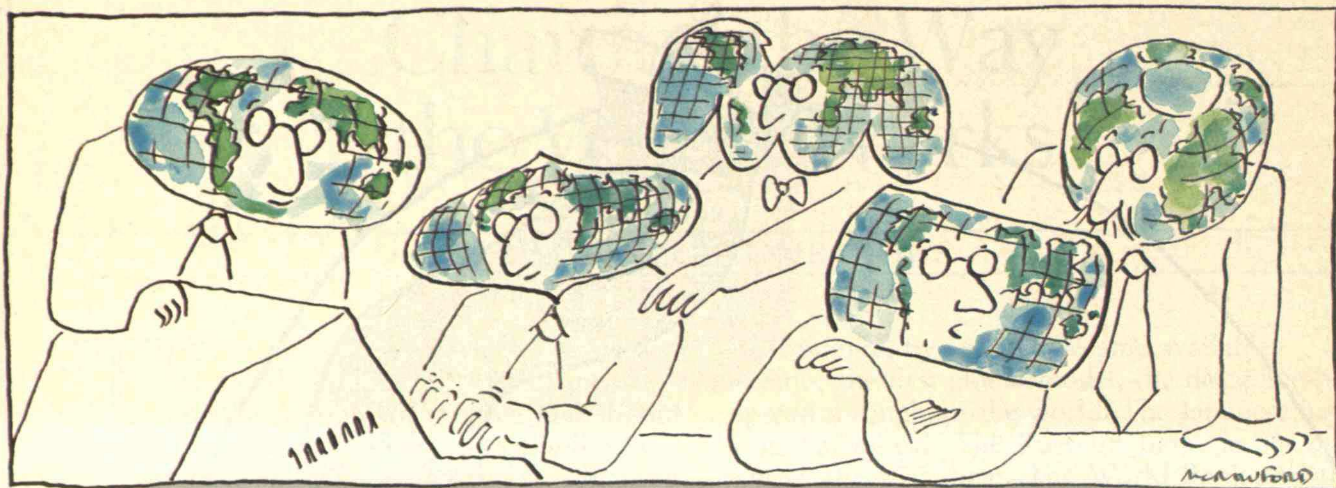
The substantive disagreements among global modelers form a catalog of the uncertainties of our era.



Then, there are substantive disagreements among the global modelers, which form a catalog of the uncertainties of our era. To what extent do free markets actually exist? How vulnerable, really, is the ecosystem? Does technology appear unexpectedly or as a result of social processes that can be controlled? Do governments act independently, and how much are they trapped by forces larger than themselves?

Above all, or perhaps I should say below all, because they are rarely addressed explicitly, are the divisive moral issues. Is man's inhumanity to man the primary global wrong, or is it destruction of the environment? What assumptions about human nature and political legitimacy do we who construct global models inadvertently build into them? What is our social responsibility: to serve a system or to challenge it, to raise questions or to provide answers, to redesign social systems or to empower others to do so?

The methods and philosophies of global modelers are so diverse that one would hesitate to call the models a single body of intellectual work, except that they are directed toward the same intertwined problems: population growth, poverty, resource scarcity, environmental deterioration, and international instability. Another point of commonality is that many of the models were made in response—sometimes heated response—to the ones that came before. Especially when the discipline first began, a major purpose of each model was to discredit the others and show how the whole exercise should be done. Thus, collectively the global models constitute a fascinating international debate. They reveal the world's knowledge, uncertainty, and opinion about global problems.

They do so in terms that are relatively precise and unemotional, adding a mathematical rigor to discussions of world issues. Every term must be defined precisely. Everything that is sold must be bought. The amounts of energy, labor, and capital allocated to various sectors of the economy cannot exceed the total amounts available. Such unremarkable and even simple-minded requirements allow more explicitness, complexity, and logical consistency than can ever be expected from the only other source of understanding about the world: the models in people's heads.

The world system is enforcing its regularities on the modelers. When the Japanese, the Soviets, the Americans, the Europeans, and the South Americans step back and attempt to integrate their most treasured assumptions about the planet, they find themselves in substantial agreement. Given the different starting points, the debate about global issues is leading to a surprising convergence of opinion.

Action and Reaction

The first global model was developed at the behest of the Club of Rome, a group of policymakers, academics, and managers who met in Bern, Switzerland, in 1970 to discuss 66 world problems such as hunger, pollution, and crime. The problems seemed interconnected, so Carroll Wilson of M.I.T., a mem-

ber of the club's executive committee, had invited someone he thought could draw the connections: his colleague Jay W. Forrester of M.I.T.'s Sloan School of Management. Forrester proposed constructing a global computer model. On the way home from the meeting, he worked out a rough model he called World1 on the back of an envelope, and then amplified it into the first detailed global model, called World2. A team headed by Dennis Meadows, then also at M.I.T., refined this model into World3, the basis for *The Limits to Growth*.

World2 and World3 are intended to answer a simple question that can be put this way: Population and capital growth are inherently exponential. The world's population is growing at such a rate that, if it were to continue, it would double in 40 years, quadruple in 80 years, and increase eightfold in 120 years. The physical growth of capital equipment, housing, and infrastructure is proceeding even more rapidly. Forrester asked what might ultimately limit population and physical growth on this finite planet, and how the world's adjustment to its limits might be smooth and controlled rather than unexpected and violent.

He concluded that no process exists that can reliably adjust today's exponential growth to the earth's limits, whatever they may be. Delays are too long, both in the process of making decisions and the time it takes for results. For example, so many children have already been born that even if each couple from now on averaged two offspring, population would continue growing for 70 years. Though industry might stop polluting, its toxic waste would linger in the environment for decades. The world's machines are too dependent on nonrenewable resources and too long-lived to be replaced quickly by machines that can use renewable resources. And the value of growth for its own sake is too deeply embedded in industrial culture for a different value to be quickly adopted.

Unless some deliberate process to slow growth is implemented, Forrester found, the most likely future will be "overshoot and collapse"—an irreversible destruction of the resource base followed by a decline in capital and population. However, if societies design a sustainable, equitable system instead of trying to correct problems caused by growth with still more growth, there are enough time and resources to provide a desirable standard of living for everyone.

The scientific community criticized World2 and World3 on several grounds, one being that they did not distinguish among different regions of the world. Thus, Mihajlo Mesarovic at Case Western Reserve University, and Eduard Pestel at the Technical University in Hannover, West Germany, designed the World Integrated Model (WIM), to explore the same questions with more regional detail. These scientists reached similar conclusions, except that their warnings were expressed in even more urgent and dire language.

Over the years WIM has been modified, updated, and made more detailed at the behest of numerous clients, including several U.S. agencies and countries such as Mexico and Iran (during the shah's regime). This is the model that is being adapted for use by the U.S. Joint Chiefs of Staff.

Another criticism of World2 and World3 came from citizens of the Third World, who read into *The Limits to Growth* the implication that growth must stop in such a way as to freeze poor nations into an eternal state of poverty. They responded with the Latin American World Model, made at the Fundacion Bariloche in Argentina. This model is constructed around an explicit value: meeting basic human needs.

According to the model, the world could work well with that priority. Latin America and Africa could meet the basic needs of their entire populations through their own efforts by the year 2000. Asia would take longer and require outside aid. The rich countries would not collapse or even stagnate, and as human needs were met everywhere, the population would stabilize.

The Bariloche group did not explicitly model environmental and resource problems. But the modelers say that the planetary stresses of a just society would be much less than those of the greed-and-growth-oriented world of today. They estimate that decent living standards could be achieved for all with per capita economic outputs a third to a fifth as great as those needed if present inequities persist.

The modelers write that "the economically underdeveloped societies cannot leave their state of backwardness following the development patterns of the already industrialized—but not necessarily developed—societies. Even if it were possible, it is not desirable, as it would mean to follow the same road which led to the present situation of wasteful and irrational consumption, accelerated social deterio-

ration, and increasing alienation."

A coalition of agronomists from Wageningen University and economists from the Free University of Amsterdam constructed a model to see if adequate food could be produced for the expected doubling of the world population—up to 6 billion by the year 2000. They discovered quickly that there is already enough food for 6 billion people, so they changed the focus of their investigation to examine why it is that in a world with more than enough food, hunger persists.

The sophisticated model that emerged, called the Model of International Relations in Agriculture (MOIRA), represents food production, consumption, and trade for 106 nations. Each has 12 income classes and a government that may interfere with internal pricing and trade flows to satisfy political priorities. As each nation tries to maintain its domestic food supplies and prices at desired levels, it dumps its shortages or excesses onto the world market. The result is systematic amplification: a small fluctuation in wheat production in Kansas can become a major wave in consumption in Ghana. Large, rich countries can buffer their interface with the world market at considerable expense but small, poor countries cannot, and fluctuations in the world market sweep into their domestic markets. As the Dutch modelers say, "He who has the lowest dam gets the whole flood."

Hunger in this model results primarily from inequities in income distribution, both among families and among nations. These inequities are exacerbated by the impersonal workings of the world market. Measures such as food aid can have adverse effects, since they lower food prices in countries receiving the aid and discourage farming. However, two kinds of policies do help eliminate hunger: changes that give poor people the resources to earn a decent income, and efforts by the rich countries to keep food exports and imports constant so as to keep world prices stable and relatively high.

When President Carter asked Gerald O. Barney at the U.S. Council on Environmental Quality to study global prospects for the year 2000, Barney gathered existing models and forecasts of various government branches. These included population projections from the Census Bureau, food projections from the Department of Agriculture, and so forth. The result, called the Global 2000 model, was not only a rich collection of information about the world, but a fascinating comment on the state of global understanding of one of the world's most information-rich governments. The separate forecasts had never before been coordinated, and their makers often were not even aware that other projections existed. The assumptions and methods of these forecasts were not necessarily consistent. Indeed, the study concluded that "at present the executive agencies of the United States Government are not capable of presenting the President with internally consistent projections of world trends in population, resources, and the environment for the next two decades."

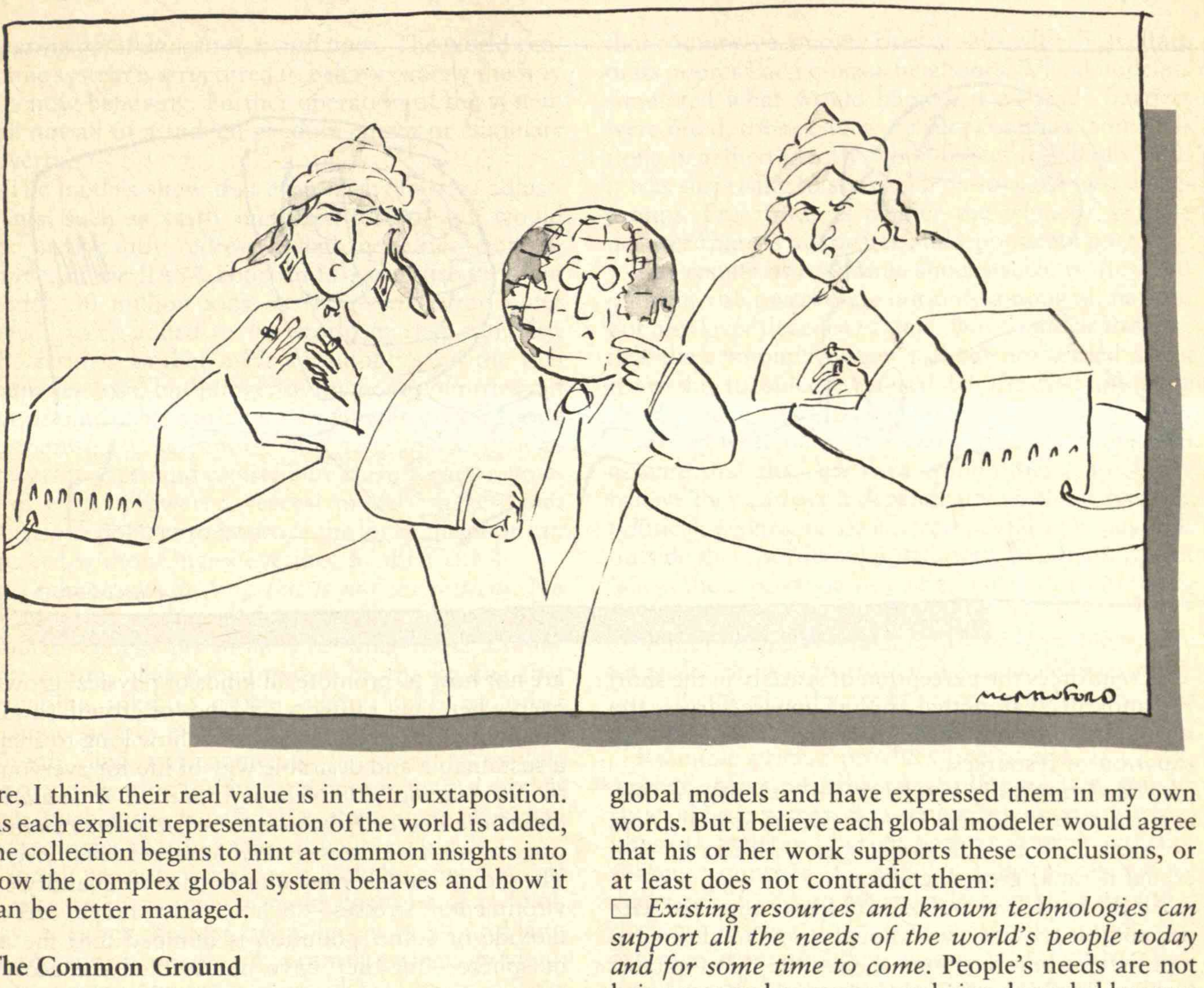
Even though these projections were not internally consistent, they were consistently gloomy. Global 2000 has become famous for that gloom, as if the study itself rather than separate government offices had produced the forecasts. The summary statement reads: "If present trends continue, the world in 2000 will be more crowded, more polluted, less stable ecologically, and more vulnerable to disruption than the world we live in now. Serious stresses involving population, resources, and the environment are clearly visible ahead. Despite greater material output, the world's people will be poorer in many ways than they are today.

"For hundreds of millions of the desperately poor, the outlook for food and other necessities of life will be no better. For many it will be worse. Barring revolutionary advances in technology, life for most people on earth will be more precarious in 2000 than it is now—unless the nations of the world act decisively to alter current trends."

The Global 2000 staff's own contribution to the bad news was to point out that the various forecasts are probably too optimistic because they were made independently. The energy forecasts assumed that enough capital would be available, the capital forecasts assumed that there would be enough energy, and the agriculture forecasts assumed that there would be enough of both. Because the sectors were not linked, as they are in most global models, they did not set up any of the truly difficult trade-offs that must be made in the real world.

These are but a few examples to illustrate the variety of the global models. Each model asks a particular question and focuses on one aspect of global complexity, each expresses the cultural and methodological viewpoint of its makers, yet each is constrained by mathematical rigor and the world database. However interesting the individual models

The media depicted the early global models as crystal balls predicting the future of almost everything.



are, I think their real value is in their juxtaposition. As each explicit representation of the world is added, the collection begins to hint at common insights into how the complex global system behaves and how it can be better managed.

The Common Ground

The common conclusions among the world models are both unsurprising and revolutionary. At some level nearly everyone understands how the world works, yet governments and people do not often operate in accordance with their understanding. While knowing that the world is an interdependent, richly varied system, we act daily as if it were made up of simple, separate pieces. Knowing that cooperation works better than competition, we continue to compete. Knowing that short-term results often differ from long-term ones, we go for the short-term payoff. Knowing that the environment flows through us with every breath, drink, and meal, we still think of nature as distinct from humanity.

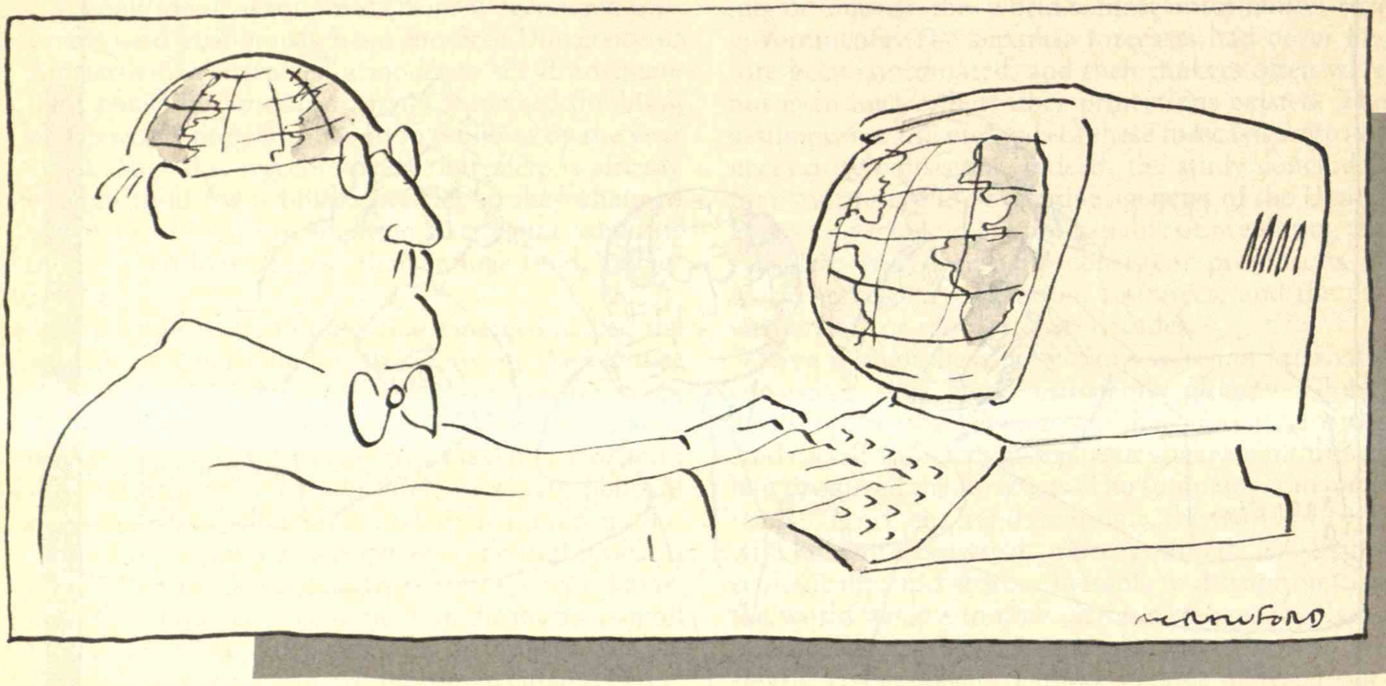
I have chosen common conclusions from the global models and have expressed them in my own words. But I believe each global modeler would agree that his or her work supports these conclusions, or at least does not contradict them:

☐ *Existing resources and known technologies can support all the needs of the world's people today and for some time to come.* People's needs are not being met and resources are being degraded because of inequities, wastefulness, and mismanagement, not because of any immediate physical scarcity.

The models illustrate this point with resounding unanimity. MOIRA shows how the world trade system transforms more than enough food for everyone into hunger for one in five. The IIASA Energy Model emphasizes how many technical options actually exist to supply energy. World3 shows how it is possible to make a transition to an economy that uses renewable resources to sustain high living standards for everyone.

The earth is a diverse, abundant planet. However, the assumption that most pervades decision making in our era is that there is scarcity. The reaction is to hoard and try to increase short-term production.

The world system is forcing its patterns on the modelers.



This reinforces the perception of scarcity in the short run and can create actual, though unnecessary, scarcity in the long run through wastefulness and degradation of resources.

☐ *Population and physical capital cannot grow forever on a finite planet.* Though overall scarcity does not now exist for the global society, it can be generated if rapid growth continues.

All the models recognize problems connected with population growth, even though some modelers began with strong reactions against the "anti-natalist bias" of World2 and World3. Agreement on the need to limit physical growth (of capital goods, infrastructure, and housing) is less unanimous, chiefly because some models represent the economy only as a flow of money rather than a stock of physical equipment. They do not account for the fact that physical equipment, like population, takes up space, requires a constant stream of energy and raw materials, and continually emits wastes.

A steady growth of electrical generating plants, factories, or any other capital equipment at 3.5 percent per year, a typical goal for industrial societies, implies a 32-fold multiplication in a century. It is not surprising that real growth rates rarely stay that high for that long. It is only surprising that so many people believe they should. The important questions are not how to promote all kinds of physical growth everywhere, but rather what kinds of growth should be encouraged in what places for how long to shape a sustainable and desirable way of life for everyone.

☐ *No reliable, complete information is available about the degree to which the earth's environment can absorb the wastes created to meet human needs.* The global models have mostly tried to quantify environmental stresses—such as how much carbon dioxide or sulfur pollution is dumped into the atmosphere—but they have not studied the ecosystem's reactions to those stresses. And even the effort to measure the stresses has shown that the data are totally inadequate. No reliable data exist on soil erosion, groundwater pollution, or disposal of radioactive waste. The makers of the U.N. World Model and WIM gave up on their environmental sectors for lack of information. Specific environmental effects, such as the death of forests in Europe, are only now beginning to be modeled seriously.

A conclusion of "we don't know" may not sound like much of a conclusion, but it is useful information in a world where policy is dominated by the belief that we do know, and that the limits to how much stress the environment can absorb are centuries away.

☐ *If continued, present policies will lead to an in-*

creasing gap between rich and poor. The world economic system is structured to behave exactly the way it is now behaving. Further operation of the system will not all of a sudden produce equity or eliminate poverty.

The models show that even fairly massive adjustments, such as vastly increased foreign aid, would not significantly redress global inequities. For example, in the IIASA Food and Agriculture Program model, 30 million tons of "free grain from outer space" were added to the world market annually. The result was that meat consumption in the rich countries rose, but hunger in the poor countries did not decline. The world system is replete with subtle mechanisms that capture any gains made in less-powerful parts and redistribute them to more-powerful parts. However, several models suggest that conscious policies to improve the lot of the poor can succeed without major sacrifice by the rich.

□ *Technology can help but is not the answer.* No set of purely technical changes tested in any of the models was enough in itself to bring about a desirable future. This is epitomized by the finding that providing infinite, cheap energy, with no other change, simply exacerbates inequality, population growth, and environmental problems. Providing land or education for the rural poor in several models was much more beneficial to them than providing technologies that increase agricultural yields.

In the process of making a global model, one has to discard fuzzy mental-model concepts of technology as either the cost-free solution to all problems or the source of all evil. From a systems point of view, technology looks more like a tool to achieve goals. If a society's goals are to maximize material possessions, resolve conflicts through military aggression, and maintain hierarchies of power, its technologies—no matter how powerful—will not suddenly produce peace, justice, or environmental quality.

□ *The interdependence among peoples and nations is much greater than commonly imagined.* Actions taken at one time and on one part of the globe have far-reaching and long-term consequences that are impossible to predict intuitively.

The models constantly surprise even their makers—as when MOIRA found that a small change in Kansas wheat production can undermine Nigerian food policy. A Japanese world model showed that that country's economy rises or falls with the welfare of its poorer Pacific-basin neighbors. When modelers simulated what would happen if all trade barriers were lifted, the results were very complex. Some nations benefited greatly while others lost badly, and it was surprising to see which nations fell into which groups. Free trade is neither the panacea nor the disaster that its advocates and opponents portray.

The results of economic shocks such as the 1973 oil price rise reverberate not only among all nations but also over decades of time. Some models indicate that the economic system still has not settled down from the turbulence caused by the first oil price shock, much less the later ones.

Most governments, especially of large nations, still assume that they can win while others lose. They believe they can act independently, without creating political, economic, or environmental repercussions outside their borders that will return to haunt them. When the repercussions come, they will continue to be surprised.

□ *Policy changes made soon are likely to have more impact with less effort than the same changes made later.* By the time the need to face a problem becomes obvious, there may be no easy solution.

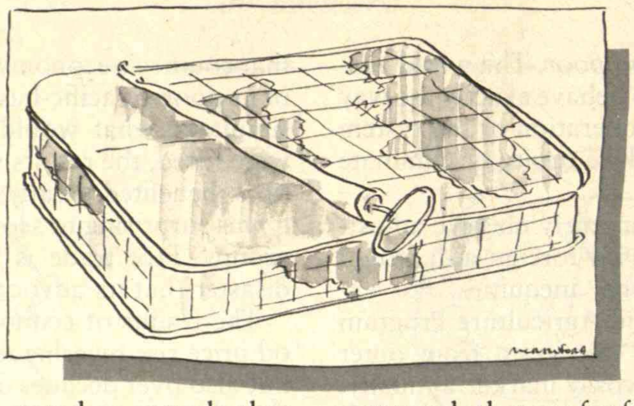
Resource pricing provides one of the classic examples of this principle. According to WIM, steady, slow oil price increases, well in advance of any actual physical depletion, benefit both producing and consuming countries. Gradually rising prices induce consumers to adopt alternatives to oil in a way that does not disrupt their economies, while producers' revenues are maintained. In contrast, the current battle between the oil cartel and the market produces disruptive price cycles in the short term and too-abrupt, too-late signals of scarcity in the long term.

Most kinds of environmental damage, such as desertification and contamination of groundwater, are thousands of time cheaper to prevent than repair. In India alone, bringing the birth rate down to two children per couple in 1995 instead of 2005 can make a difference of 300 million people. Creating equitable distribution systems is far less painful while there is still an abundance to distribute. But policymakers systematically postpone all such decisions as long as possible.

□ *Many complex international programs and agreements are based on inconsistent assumptions.* Policymakers debate plans that are simply impossible to

Exponential growth cannot continue forever on a finite planet.

achieve while failing to notice real opportunities.



For example, several global-modeling teams have tried to find ways to meet the Lima targets developed by the U.N. Conference on Trade and Development, which specify what shares of world industrial output the Third World should provide by the year 2000. However, these targets were stated so vaguely that the teams could not represent them quantitatively without further interpretation. After representing them as best they could, the teams found the targets essentially unmeetable. And when they forced massive, unrealistic changes on the system so the goals could be met, the modelers found them not even desirable. For example, the Latin American World Model found that for Africa to produce the stipulated amount of manufactured exports, food production, education, and housing would have to decline.

If global models had no other use, they would be worth the price of making them just to impose clarity on the terms of international demands and agreements, and to save the trouble of arguing for conditions that are patently impossible to achieve. One case where a model has been used successfully for just such a purpose is in the Law of the Sea negotiations. Professor J. Daniel Nyhart of M.I.T. developed a model of the costs and returns of undersea mining that was used to debunk initial assumptions that this technology would yield a bonanza. The model enabled the negotiators to agree on international licensing and taxing systems.

A New World

Although something within us knows better, our mental models and those of our leaders cling desperately to the assumption that the future will not be very different from the present. Or that the future will be some smooth extrapolation of the present. Or at least that the future is to be predicted, not to be shaped by human decisions.

It is not possible to maintain those assumptions while contemplating the long-term trends of the world. Global models produce thousands of different simulated futures under thousands of possible sets of policies. None of those simulations proceeds far past the year 2000 without showing significant changes for better or worse. A smooth continuation of present trends can be ruled out as physically impossible.

One hardly needs a computer model to discover current trends that are far from sustainable. The world's use of nonrenewable resources such as petroleum cannot continue indefinitely. The amount of carbon dioxide in the atmosphere—up 30 percent since preindustrial times—cannot continue increasing without disrupting the global climate. Each year 20 million acres of tropical forest disappear, and there are 80 million more people to feed. Each minute the world spends $1 million on armaments and 24 people starve, most of them children.

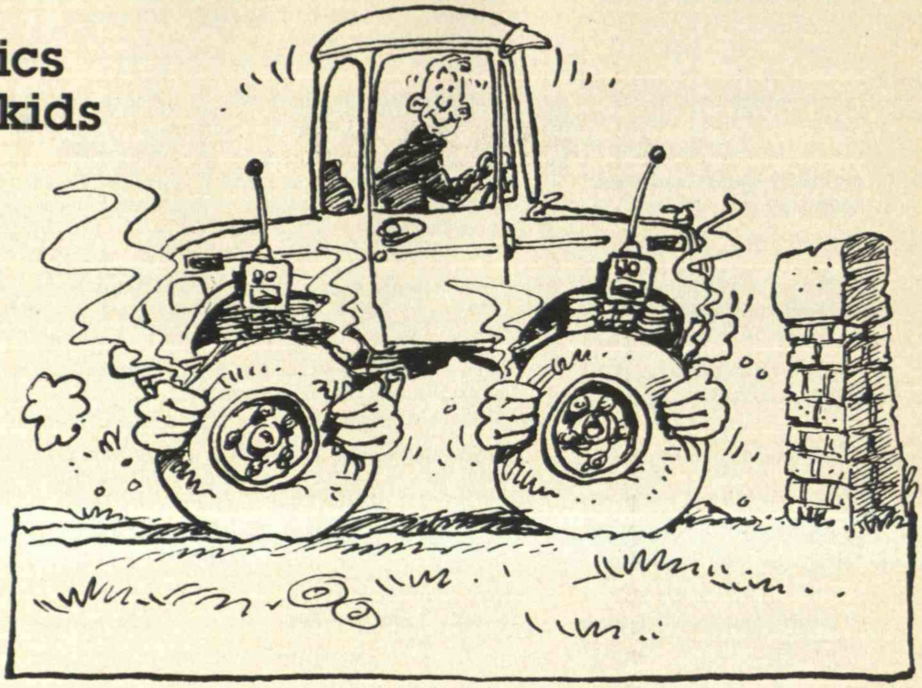
The range of *real* possibilities includes some nearly unimaginable outcomes, including on the one hand nuclear winter and the end of everything, and on the other a world at peace in which everyone's physical needs are met sustainably. Both these futures are, as far as our present knowledge can tell, very possible, and the difference between them will be determined by the way the world's people understand their options and the way they act.

The global models have not given us the key to full understanding of our complex world. We will probably never have that key. What the global models have done, at least for those of us most closely involved with them, is to be what Stuart Bremer, director of a global-modeling group at Science Center Berlin, calls a "creative irritant." They have forced us to stand back and look at all the complexity, admit it, be humbled by it, and yet continue to keep confronting it. When we do, we see far too many negative trends to be complacent and far too many positive trends to be hopeless. We mainly see a lot of work to do.

DONELLA H. MEADOWS, adjunct professor of environmental and policy studies at Dartmouth College, worked in the System Dynamics Group at M.I.T. on the first global model. She is coauthor of Groping in the Dark *(Wiley & Sons, 1982), a description of the first seven global models, and is a research scholar of the International Institute of Applied Systems Analysis in Laxenburg, Austria.*

NAME OF MODEL	PROJECT LOCATION	FOCUS OF INVESTIGATION
WORLD2 WORLD 3	M.I.T.	Interaction of growth with physical limits
WIM (World Integrated Model)	Case Western Reserve University, Cleveland, and Technical University, Hannover, West Germany	Interaction of population, economics, and trade; regional differences
Latin American World Model	Fundacion Bariloche, Rio Negro, Argentina	Alleviation of poverty, maximization of life expectancy
MOIRA (Model of International Relations in Agriculture)	Free University, Amsterdam, and Agricultural University, Wageningen, The Netherlands	Impact of world trade and government protectionism on world hunger
SARUM (Systems Analysis Research Unit Model)	Department of the Environment, London	Effect of resource constraints on economic growth; role of market
FUGI (Future of Global Interdependence)	Engineering Research Institute, Tokyo University	Economic forecasting, industrialization of poor countries
United Nations World Model	New York University and Brandeis University	Impact of resources and environment on economic development
GLOBUS (Generating Long-term Options by Using Simulation)	Wissenschaftszentrum, Berlin	International relations, trade, and conflict
SIM/GDP (System for Modeling Global Development Processes)	All-Union Institute for Systems Studies, Moscow	Impact of social structure on economic development
Basic Needs Model	International Labor Organization, Geneva	National vs. international policies for meeting basic human needs
Regional World IV	Aid Association for Lutherans, Appleton, Wisconsin	Role of values and social relationships in solving world problems
Interfutures	Organization for Economic Cooperation and Development, Paris	Implications of world developments for OECD domestic and foreign policies
Global 2000	U.S. Council on Environmental Quality, Washington, D.C.	Structure of U.S. government's global model
AREAM (Australian Resources and Environmental Model)	Griffith University, Queensland, Australia	Impact of world developments on Australian resources and environment
IIASA Global Energy Model	International Institute for Applied Systems Analysis, Laxenburg, Austria	Long-term options for global energy supply
FAP Model (Food and Agriculture Program Model)	International Institute for Applied Systems Analysis	World food production and trade system
AIM	U.N. Institute for Training and Research (UNITAR), New York	North-South relations, equitable distribution mechanisms
(No model name)	Institute of Economics and Industrial Engineering, Novosibirsk, USSR	World financial balance with rising energy prices
GBSM80 (Global Biosphere System of Models)	Computer Center of the USSR Academy of Sciences, Moscow	Interactions between human activities and the biosphere
Integrated System of World Models	University of Bradford, U.K.	General forecasting and policy analysis

Using Electronics to Get Off the Skids



New technology just appearing in U.S. automobiles may largely eliminate one of driving's most terrifying situations: the uncontrollable skid that results all too often when a panicked driver slams on the brakes and the wheels lock. Antilock brake systems, available for some years in Europe, are now being offered on certain Ford and Mercedes-Benz models produced for the U.S. market. "All the driver does is push the brake pedal to the floor," says A.B. Schumann of Mercedes-Benz. The antilock system ensures that braking will be efficient.

Except on a smooth, dry road, maximum braking efficiency generally occurs when the wheel is rotating somewhat more slowly than it would if rolling freely, but not when it is locked. More important, if the wheels lock, the car can't be steered. "As soon as the wheel ceases to roll, the tire essentially behaves like a sliding brick," says Dick Rasmussen, head of the brake, tire, and steering group at the General Motors Proving Ground.

The antilock system doesn't affect normal braking; it comes into play only when the wheels are about to lock. The system determines that this is happening by monitoring almost instantaneous changes in wheel speed. Sensors on each wheel (Mercedes has one for both rear wheels) send electrical signals indicating turning speeds to a microprocessor. If lockup is imminent, the microprocessor triggers electrically controlled valves to lower hydraulic pressure in the brake lines and reduce the braking force. When the wheels are rolling satisfactorily, the microprocessor increases hydraulic pressure. If lockup approaches again, the cycle repeats. The systems are very fast, adjusting pressure as often as 10 or 12 times a second.

"Controlling wheel lock won't make a car skidproof," says Rasmussen. Too ambitious a maneuver on too poor a road will always cause a skid. But antilock braking does significantly extend the limits of control. In one Mercedes test, drivers slammed on the brakes in cars traveling with both righthand wheels on simulated ice and lefthand wheels on dry pavement. Cars without the antilock system promptly spun out of control; those with the system steered well and could be stopped straight.

Unfortunately, the systems are expensive now. In the United States, antilock braking is standard equipment on five Mercedes models and a $1,200 option on two others, and Ford offers it as standard only on certain Lincoln Mark VII and Continental luxury cars. "It's not clear whether or when these systems will appear in cheaper models," says James Womack of the Center for Transportation Studies at M.I.T. General Motors and Chrysler are both doing development work on antilock systems. They won't discuss when they might put them on the market, though there's a rumor that next year's top-of-the-line Chevrolet Corvettes will have them.

If antilock braking is commercially successful, its ability to monitor wheel speed might well be exploited further. "Slip control is the next step," says Schumann. This would in effect be the inverse of antilock braking: it would control engine speed to prevent wheels from spinning during acceleration, particularly on slick surfaces. Volvo has already demonstrated a prototype antislip system, and Mercedes says it's well along in developing one. However, nobody has set a date for introducing this technology on the market.—*David Kennedy* □

Candle in a Nuclear Plant: Ten Years Later

On March 22, 1975, a single candle ignited a fire at the world's largest nuclear plant. The incident cost utility customers $213 million and revealed weaknesses in fire protection at nuclear plants nationwide. Ten years later, at a cost of $20 million to $50 million per plant, utilities are still working to meet regulations that resulted from the event.

Often cited as the nation's worst reactor accident before Three Mile Island, the fire at Browns Ferry Nuclear Plant near Athens, Ala., showed that inadequate fire protection could lead to damage of the reactor core. The fire began when a worker, testing for air leaks with a candle flame, ignited polyurethane

ILLUSTRATIONS: JON McINTOSH

foam used as a sealant where electrical cables ran from one room to another. Despite repeated dousings with carbon dioxide, the fire burned for seven hours before it was completely extinguished. Although operators at the Tennessee Valley Authority (TVA) plant were able to shut down and safely cool the two reactors involved, the fire damaged 1,600 electrical cables, including circuits that controlled the emergency core-cooling systems of one of the reactors.

The incident revealed a basic design flaw in nuclear plants: when cables controlling redundant safety systems are too close together, a fire in one set of cables can render both safety systems useless. Shortly after Browns Ferry, in a regulatory-guidance statement, the Nuclear Regulatory Commission (NRC) proposed a way to ameliorate this problem. However, when the NRC's solution was tested in a fire at Sandia National Laboratories, the backup cables were destroyed. Thus, in 1981 the NRC issued a stricter fire-protection regulation giving specifications for separating cables.

Industry representatives generally support the intent of the rule. However, when the NRC began inspecting plants about two years ago, it discovered that utilities either didn't understand the rule or were having trouble implementing it, says Jim Taylor, NRC deputy director of inspection and enforcement. Wade Larsen, a technical consultant for the Nuclear Utilities Fire Protection Group, says that because the rule is unclear, utilities have spent unnecessarily large sums in attempting to comply with it.

The NRC has set up regional workshops to help utilities understand the rule, and they are meeting it in "varying degrees," Taylor says. Larsen predicts that a majority of plants will be in compliance by the end of 1985. However, Browns Ferry still faces two to three years' work before it will comply, and the startup of another TVA plant, Watts Bar, has been delayed six months because of failure to meet the requirement.

Not Safe Enough?

Even if utilities met the rule, fire protection at nuclear plants would remain inadequate, charges Bob Pollard, a nuclear safety engineer with the Union of Concerned Scientists. He says that the NRC fire regulation weakens the "single-failure" rule that applies to other safety systems. In general, the NRC requires that the emergency safety system must be able to function after an "accident sequence"—if a broken pipe in the cooling system causes other components such as pipes or gauges to fail, for example. Furthermore, this system must continue to function even if there is another unrelated failure of any component.

After a fire, which is more likely to occur than many other accidents, says Pollard, NRC regulations require only that one cable network be available to maintain "hot shutdown"—keep the plant shut down, but at a temperature of more than about 300° F. The cable network is not required to function after an additional unrelated failure. And no systems are required to survive a fire and maintain "cold shutdown"—keep the plant shut down at a temperature of less than about 300° F. The utility merely must convince the NRC that it could repair the

necessary systems to achieve cold shutdown within 72 hours. "To pretend that you can fix damage without knowing what it will be is ridiculous," says Pollard.

While U.S. utilities worry about distances between cables, Swedish utilities have used a different approach, keeping cables that require separation in different rooms.

U.S. utilities could do likewise, Pollard says; the added construction costs would be offset by the savings from not having to implement the present rule.

Practical Firefighting

Other lessons from the fire have been less controversial. An obvious one is that candles should not be used to test for air leaks. One NRC report suggests that the TVA should have learned that lesson sooner, noting that the candle technique had started several small fires at the plant before the 1975 incident. The NRC has also banned the use of polyurethane foam as a sealant around the cables.

The incident also revealed industrywide confusion over how to put out an electrical fire. Most people, including engineers, are taught that using water on an electrical fire will cause electrocution and short-circuit wiring. With the use of special nozzles to prevent electrocution, however, water can sometimes be more effective than carbon dioxide. If water had been used at the outset of the Browns Ferry fire, the incident would have been minor, says Victor Benaroya, NRC chief of chemical engineering. The NRC now requires nuclear plants to have both the special nozzles and trained, five-person fire brigades.

How could the industry have overlooked such basic safety measures? John Garrick of Pickard, Lowe and Garrick, Inc., a firm that performs risk assessments of nuclear plants, suggests that the nuclear industry might have focused its safety concerns on systems directly related to nuclear phenomena, rather than on the equally critical but less obvious conventional systems.—*Laura Simmons* □

Up in Smoke: Stove Programs Face Reality

More than 100 million people in developing countries suffer chronic shortages of fuelwood, according to the U.N. Food and Agriculture Organization. Over the past five years some 100 governmental and private programs have tried to help these people by introducing cheap but efficient wood stoves. Most are "rural mud stoves" made of sand and clay by the users themselves or by fairly unskilled workers. For example, in Central America the stoves are called *Lorena* and in Senegal the *Ban ak Suuf*; in India the traditional *chula* is being improved.

Such stoves were expected to multiply spontaneously as neighbor showed neighbor how to build them. Tens of millions of stoves would be built, it was thought, making life easier for the world's poor and stemming deforestation.

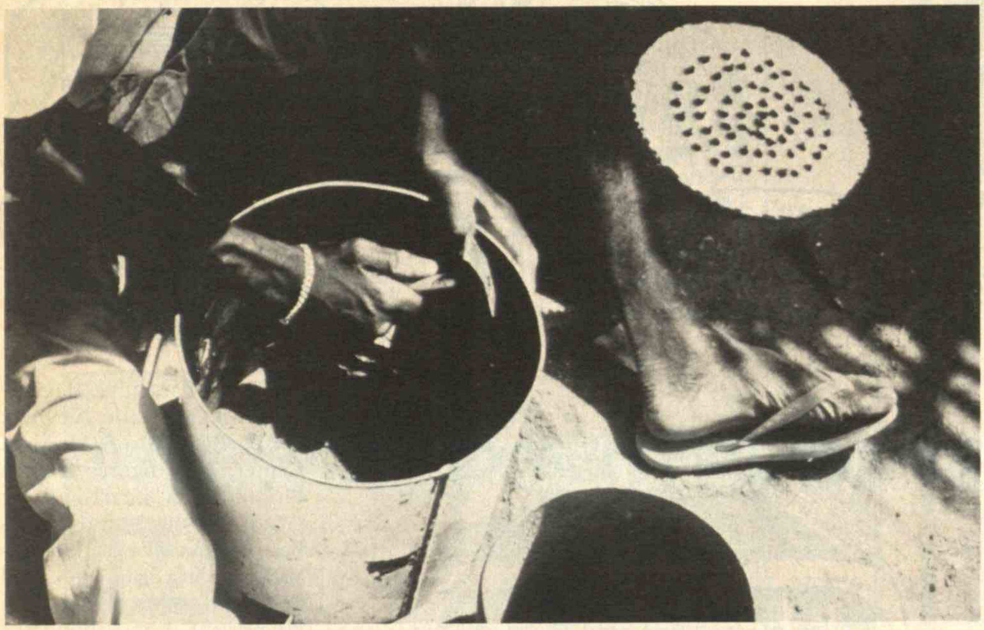
Sadly, almost all these programs have failed. Fernando Manibog of the World Bank estimates that only 100,000 stoves have been built worldwide, only half to three-fourths of which are still in use. No national fuel shortage has been eased, and even local savings are doubtful.

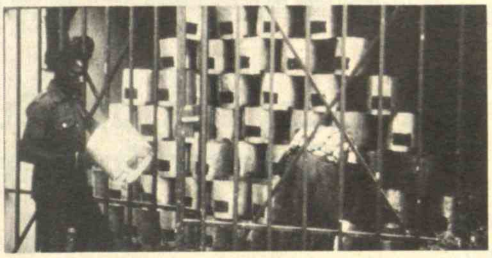
Wrong Stoves

The wrong stoves were promoted for the wrong reasons in the wrong way, according to a 1983 report from Earthscan, the information service of the International Institute for Environment and Development. The IIED is funded by the World Bank, the U.N. Development Program, national governments, foundations, and corporations to do research on international development and provide assistance to the Third World.

The report points out that stove promoters underestimated "the formidable competition of the three-stone fire"—a triangle of stones on which a pot can be balanced. This is probably the world's most widespread and versatile cooking technology. It cooks and smokes food, lights the home, repels insects, and serves as the social and ceremonial center of family life. Features such as chimneys

PHOTOS: VOLUNTEERS IN TECHNICAL ASSISTANCE





Opposite: The Central American *Lorena* is one of the "rural mud stoves" that government and private programs have promoted around the world during the past five years to ease fuel shortages. However, in practice, these stoves are little more efficient (if at all) than what is probably the world's most wide-spread cooking technology: the three-stone fire (bottom, left). And the fire has many benefits that the stoves lack: it not only cooks but provides light, repels insects, and serves as a center of family life.

Developers hope that centralized distribution of efficient metal or ceramic stoves will be practical in cities and towns. Urban areas consume most of the wood and charcoal in many countries. Top: A portable metal stove being made in Upper Volta. Bottom right: A stock of finished stoves.

and enclosed fireboxes designed to improve efficiency eliminate many of these benefits.

Then there is the embarrassing question of efficiency itself. John Lippert of Volunteers in Technical Assistance (VITA), a Washington-based organization for furthering international development, says that even a good stove has a surprisingly small advantage in efficiency over a well-tended open flame: 17 or 18 percent compared with 13 or 14. And in actual use many stoves consume at least as much fuel as the ancient three-stone fire. Improper construction is a major reason. "It's very hard to get the critical dimensions for efficiency without highly trained craftspeople," says Lippert. Misuse and deterioration lower efficiency further—the mud stoves crumble within a year or two, and many of them are simply abandoned.

Stoves will not soon reduce fuelwood consumption and will never make inroads into general deforestation, says Manibog: "The main cause of deforestation is not fuel consumption but the spread of agriculture." Thus, many critics have called for scrapping the effort to promote stoves altogether.

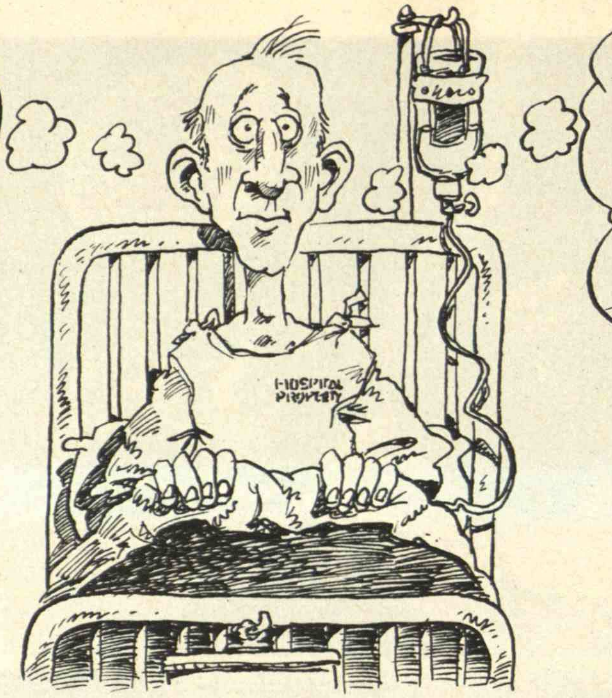
A Better Way?

Manibog, Lippert, and the Earthscan team believe that would be unwise. Promoters generally favor a new approach based on more durable, efficient—and costly—"second-generation" stoves made of metal or ceramic. Dubious about folk dissemination, promoters would like to help craft workers become "stove entrepreneurs," selling the technology in cities and towns. This will make a dent in fuel consumption because urban areas consume most of the wood and charcoal in many countries, drawing supplies from the surrounding countrysides. Also, centralized manufacture and effective distribution are possible in cities. Since town dwellers are likely to buy, rather than gather, fuel, they have a cash incentive to purchase efficient stoves. And they are generally more receptive than farmers to innovation.

With startup help from the government, Kenyan stove builders and door-to-door salespeople have turned an efficient bucket-shaped charcoal burner into a standard household item. And Nepal has an ambitious program underway to market centrally built ceramic stoves.

Second-generation stoves may help rural wood gatherers by cutting urban fuel demand and lessening competition from professional woodcutters. Promoters also hope that urban stoves will become popular in the countryside, but that development could take a long time.—*Duncan M. Brown* □

Coronary Bypass Surgery: A Growth Industry



Coronary bypass surgery is a "middle-class fad," says Dr. Thomas Killip, chairman of the Department of Medicine at Beth Israel Medical Center in New York.

Physicians do not dispute that bypass surgery can save the lives of patients with severe heart disease. When an artery supplying a patient's heart with blood becomes clogged, a surgeon replaces it by transplanting a vein or artery from another part of the body. This major open-heart procedure can also improve the lives of those who suffer from angina (chest pain associated with heart disease) that cannot be alleviated by drugs or other nonsurgical treatments.

However, surgeons are performing too many bypasses, says Dr. Joseph Stokes, professor of medicine at Boston University. Stokes, who has worked for some 30 years with the Framingham (Mass.) Heart Study, supported by the National Institutes of Health, says less costly and intrusive treatments are often preferable for heart-disease patients. For example, a recent study by the National Heart, Lung, and Blood Institute (NHLBI) showed that drugs known as "calcium blockers" could dramatically lower the chance that patients with heart disease will die from heart attacks.

Birth of an Industry

Two major studies have shown that coronary bypasses neither lengthen nor improve the lives of patients, except in the most serious cases of heart disease. Between 1970 and 1974 physicians at the Veterans Administration (VA) assigned heart patients randomly to two groups: one received coronary bypass surgery; the other was given drugs or other nonsurgical treatments. In 1977 *The New England Journal of Medicine* published the results: there was no difference in survival rates. Many surgeons and other doctors were skeptical, but in 1983 these results were essentially corroborated by a second study supported by the NHLBI.

In an editorial accompanying the report of the VA study, Dr. Eugene Braunwald of Harvard Medical School wrote that "the enormous funds" being devoted to coronary bypass divert support from "other, perhaps more necessary, aspects of medical care." And he warned of "an even more insidious problem"—namely that "an 'industry' is being built around this operation."

In 1977, the year Braunwald wrote his editorial, 70,000 bypasses were performed at an average cost of $12,500. By 1983, the last year for which figures are available, 190,000 bypass operations were performed at an average cost of $20,000. It had become a $3.25 billion industry.

Not all doctors concede that too many bypass operations are being performed. Dr. Victor Parsonnet, director of surgery at the Newark (N.J.) Beth Israel Medical Center, cites figures from a Philadelphia heart-surgery group showing that the number of bypass operations actually declined in 1984, and he says there has been a 10 to 20 percent drop around the country. Parsonnet attributes this leveling off to the fact that most patients who needed bypass have received one by now.

However, Dr. Thomas A. Preston, chief of cardiology at Pacific Medical Center, wrote in *The Atlantic* that coronary bypass operations continue to be overused because they are so lucrative for hospitals and surgeons, who typically earn $5,000 per operation. There are other incentives also. Like other high-tech procedures, bypass surgery is often regarded as a "magic cure," says Stokes. "Many doctors like to have a technical solution for everything."

Impatient Patients

Nor are patients merely passive participants in the growth of bypass surgery. "Some individuals don't want to take medicine three or four times a day because pill popping is a constant reminder of a potentially fatal condition," says Stokes. Thus, they actively seek bypass operations. He tells of patients who

changed doctors until they found one who would operate.

Stokes does not believe that normal medical review procedures can effectively curtail the overuse of bypass surgery. "It's almost impossible to make doctors act as police," he says. "It is very hard for a young cardiologist to blow the whistle on a senior surgeon in the hospital by not approving a case."

Stokes says the increasingly popular health maintenance organizations (HMOs) provide a way to reduce unneeded surgery. HMO patients pay regular, fixed fees to cover all medical procedures, and to stay competitive, HMOs seek to keep these fees low. That means avoiding expensive, unnecessary operations.—*Phyllis Wollman* □

A Nonsurgical Alternative

Medical researchers have recently developed a nonsurgical method of treating heart disease that, in some cases, is just as effective as coronary bypass surgery but is much less expensive and disabling. Rather than replacing a clogged coronary artery with one taken from elsewhere in the body, the physician relieves the obstruction by stretching the artery.

In the technique, called "transluminal angioplasty," a hollow flexible tube (catheter) is inserted into either the femoral artery in the groin or the brachial artery in the upper arm. A physician guides the catheter to the obstructed area of the coronary artery, observing its progress by means of a televised x-ray image. Then the physician passes a smaller, balloon-tipped catheter through the guiding catheter. The balloon tip is inflated one or more times to exert pressure on the obstructed area and widen it. For this reason, the procedure is sometimes referred to as "balloon angioplasty."

This procedure is essentially nonsurgical—it doesn't require opening up the chest—and it is done under local anesthesia, while bypass surgery requires general anesthesia. If the angioplasty is successful, the patient can usually leave the hospital in two or three days and return to work in a week or two. In contrast, the average open-heart-surgery patient must stay in the hospital for about a week and then spend 6 to 12 weeks recuperating at home. The cost of the nonsurgical technique is also significantly lower.

At this point, the ideal candidate for this procedure has only one narrowed artery with an obstructed area that is short and flexible enough to be stretched. Only about 5 to 10 percent of all patients considered for bypass surgery have such an obstruction. But for this limited group, the results of the angioplasty procedure compare favorably with those of surgical treatment, and physicians are beginning to test its effectiveness on people with obstructions in two or more arteries. □

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Violent storms rage in the deep ocean, transporting huge loads of sediment for great distances along the bottom. Only recently discovered, these storms may have far-reaching implications.

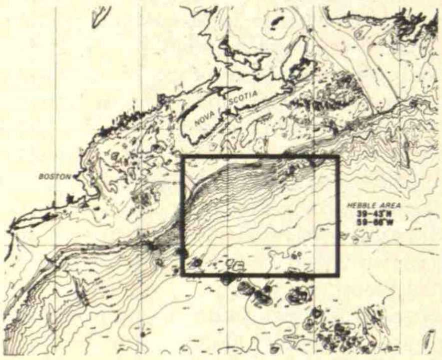
These Deep Waters Don't Run Still

BY VICTORIA KAHARL

OUR second night at sea, the marine geologists aboard the research vessel *Knorr* gather in the chief scientist's cabin to look at photographs of the ocean bottom. The photos have been taken by "Pogo," a strobe-equipped camera mounted on a steel frame that bounces across the seabed, each bounce triggering the camera's shutter. Pogo snapped its first shot at 5:50 P.M., after a two-hour journey by winch to the bottom nearly three miles below, and by 9 P.M. the slides are ready to go.

The geologists can hardly contain their excitement at the bumps and lumps on the screen before them. "Look," I.N. (Nick) McCave shouts. "A fairy ring." In his clipped Oxford accent, McCave explains that the strange mound with five symmetrical holes was apparently made by an animal, perhaps of the phylum *Echinodermata*, which includes starfish and other five-sided creatures. Another slide. "Oh!" says Charles Hollister. And another. "Ah," McCave chimes in, pointing his bare foot to make a long shadow across the screen. "Go back, Charley, go *back*!"

The researchers aboard the R/V *Knorr* are hunting for telltale signs of something that until recently was not thought to exist—an extraordinarily strong current, or "benthic storm," on the bottom of the deep sea. People had long believed that "the deep waters are a place where change comes slowly, if at all," as Rachel Carson wrote in her classic *The Sea Around Us*. But the results of the High Energy Benthic Boundary Layer Experiment (HEBBLE), of which this cruise is part, have helped dispel the notion of a tranquil abyss. Deep and dark it is; calm and unchanging it is not.



VICTORIA KAHARL is a science writer at Woods Hole Oceanographic Institution and project coordinator of HEBBLE.

Since HEBBLE's modest beginning in 1979, some three dozen scientists of varying disciplines have participated in the project, which is funded by the Office of Naval Research. The experimental site is in the North Atlantic about 450 miles off the coast of Massachusetts. There project scientists have detected massive, fast-moving storms sweeping along the bottom. They have been recorded moving at speeds of up to 75 centimeters per second—about one knot—exerting a force equal to a 60-mile-an-hour wind on land. Deep-sea currents ordinarily creep along at about 5 centimeters per second.

Storms can carry a ton of sediment a minute, causing dramatic changes in the sea floor—scouring it in some places, depositing enormous loads of clay and silt in others. "A benthic storm is very much like a blizzard," says Arthur R.M. Nowell of the University of Washington, codirector of HEBBLE. "The visibility goes to zero. Then the weather clears and you can see small ripples of mud in striking patterns much like drifts of snow around fences and trees after a real whiteout."

Scientists are not yet able to predict when benthic storms will appear, although preliminary data put their frequency at about every two to three months. The storms last from a few days to two weeks and can affect areas tens of kilometers wide.

What causes the storms is also still uncertain. However, Charles Hollister, codirector of HEBBLE and senior scientist and dean of Woods Hole Oceanographic Institution, claims researchers are "very close" to an answer. Their results appear to link the storms to the nearby Gulf Stream and the surface eddies it sheds—

 PHOTOGRAPHS: SUKI COUGHLIN

Ready to plunge to the seabed nearly three miles below, this instrument is part of the High Energy Benthic Boundary Layer Experiment (HEBBLE). The study site is about 450 miles off the New England coast (opposite).

The Case of the Missing Mooring

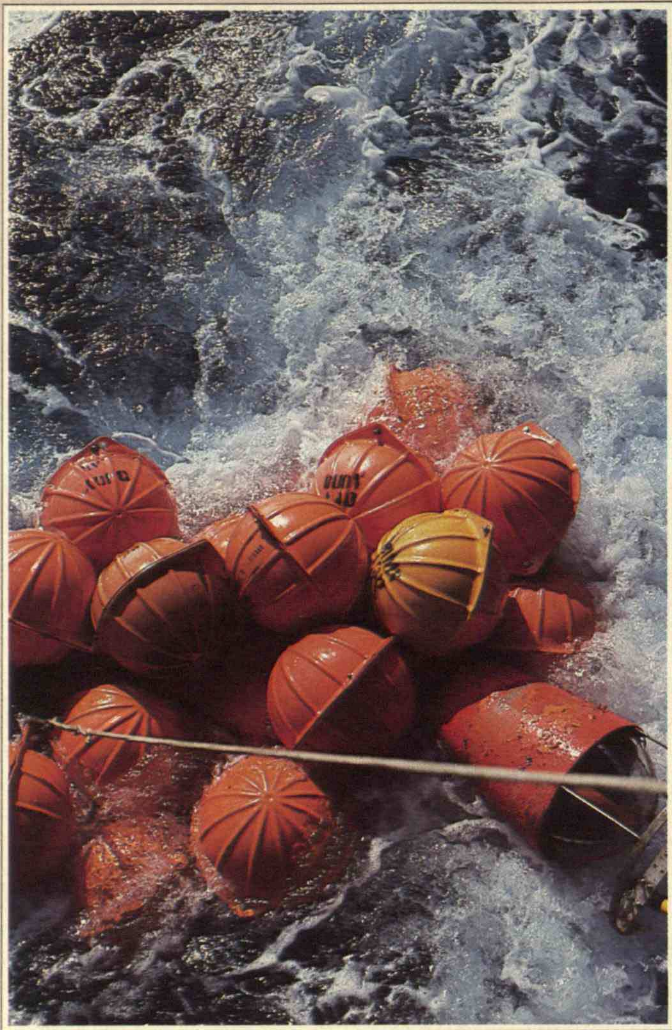
HEBBLE research cruise:
Journal entry for Sunday, August 26, 1984. V. Kaharl

0400: "I'd love to catch that bastard," says George Tupper, an engineer from Woods Hole Oceanographic Institution. He is hunched over the echo sounder, watching its belt sweep across the paper every second and leave jagged maroon lines. For so many thousands of seconds, he has been intently watching the sounder and listening to its monotonous pinging.

Tupper's invective is directed at mooring 778, from which two meters that measure deep-sea currents are suspended. The mooring is somewhere out there in the black water of the North Atlantic off Massachusetts, anchored to the bottom nearly three miles beneath us.

The mooring should have surfaced automatically when summoned by an acoustic signal. But something went wrong, and George has been trying to catch it since yesterday morning. We have almost 7,000 meters of cable paid out, hoping that a single hook on this line will somehow meet up with the mooring, which rises only about 800 meters off the bottom.

"We ain't making too much headway now, are we?" says second mate J.P.



Among the loud, regular pings from the echo sounder, we hear the faint, lower-pitched pings from the mooring. Its batteries are weak and getting weaker. Tupper smiles when he picks up a porpoise gurgle. "You hear that?" he says, shaking his head. "Little devil." The animal is "talking" to the echo sounder, masking the weak signals from the mooring.

The current has pushed us too far west so we turn, making a large southwesterly sweep. The cable trails us. Will it straighten out by the time we pass over the presumed location of the mooring? Is the hook on the cable trailing deeply enough? The only certainty is that the stubborn cable is virtually impossible to control. The ocean is in command here. Its bag of tricks is much deeper than ours.

But George thinks he knows where the mooring is—he has fixed its general position. That, it seems, was the easy part. "Lots of water," J.P. says.

What an understatement. Tupper says he has "only a 40 to 60 percent chance" of retrieving the mooring. Engineer David Hunley of Flor-

rings of swirling water hundreds of kilometers across. The kinetic energy of these eddies is somehow transferred downward and generates a current that joins and reinforces the normal current on the sea floor, which in the HEBBLE area is unusually strong for the deep sea. This enhanced current becomes a storm when it grows strong enough to lift copious amounts of bottom sediment.

Evidence that energetic surface eddies combine with stronger-than-normal bottom currents to generate benthic storms is "too strong to be coincidental," says Hollister. This link is also bolstered by the fact that the largest sediment drifts on the sea floor are found in the coupled areas. Thus, Hollister says, it may be possible to identify other areas likely to experience benthic storms by sandwiching world maps showing areas of strong bottom currents with those showing energetic surface eddies. "When you do this, you find that the proper conditions exist in numerous areas," he says. "These include the entire northwestern part of the North Atlantic basin and vast areas off the coast of South Africa, Argentina, and New Zealand."

Good News and Bad News

The discovery of powerful benthic storms, which the scientific community is only now beginning to appreciate fully, will likely have far-reaching implications. The storms may become an important factor in the design and placement of virtually any object meant for abyssal depths in potentially stormy areas.

For example, Hollister says the storms might be able to sweep sediment out from under seabed telephone cables, causing them to "strum," weaken, and fail. Trouble with telephone cables in the deep sea is rare, according to AT&T senior engineer Jeff Ewald. Indeed, the company's transatlantic cables have experienced only minor problems over the years. But AT&T has recently received some "inexplicable" transmission signals from its TAT-7 transatlantic cable that skirts the HEBBLE ex-

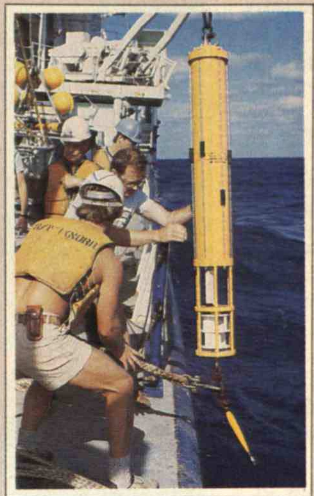
ida State University likens George's effort to trying to dangle a threaded needle from the top of the Empire State Building into a bottle on the sidewalk.

George is in surprisingly good humor. Only puffy eyes and an occasional long pause between words show his need of sleep. He is as gracious when I bring him coffee and an apple as he was last night when I brought him a lukewarm beer and a sandwich.

Tupper watches the tensiometer. If the tension suddenly peaks, it will mean we've got something.

0455: The sun starts its daily lavender paint job on the horizon. Physical oceanographer Georges Weatherly of Florida State University arrives with coffee and a fresh pack of cigarettes for roommate Tupper. In Weatherly's quiet presence I sense a deeply rooted camaraderie that seems to bind all ocean-going scientists in their battle of equipment against the sea.

Suddenly the tensiometer needle swings sharply to the right. "Bridge, we got tension coming up over 9,000," Tupper says, his voice hardly showing excitement. "And you know what I'm hoping."



George Tupper, wearing a white tee-shirt, peers over the side of the R/V *Knorr*. He has been hunting for a mooring attached to the seabed, from which two meters that measure currents are suspended. The mooring should have surfaced automatically, but something went wrong. The crew dragged a trawl line behind the ship to break the mooring's anchor cable, and flotation spheres lifted it to the surface (opposite). To the relief of the *Knorr* crew, one of the meters was still attached (above, right).

Tension rises: 11,000 to 12,000. The needle trembles at 15,000 pounds of tension on the line.

Just as suddenly, the needle drops off sharply. Does this mean the cable hooked the mooring only to lose it? Our instruments offer no precise information. The only way to know is to reel in the trawl.

Tupper finally gives the order. He hasn't got much choice: his time is up. Time is expensive at sea. It costs about $15,000 a day to operate a research ship like the R/V *Knorr*. And other activities are scheduled for today, indeed for every day and every hour of the cruise.

The cable pulls in at a fairly steady 3,000 pounds of tension. Weatherly is cautiously optimistic: he expects the tension would be less than 1,000 pounds if the line were empty. "There *is* a possibility," he says, shaking his head. "What a business."

0750: The thick steel trawl line and its hook are on deck. Empty.

0810: The captain spots what he says appears to be "a life raft or something." He asks if we should take a look. "What the hell," says Tupper.

It turns out to be not a raft but the luster of bright orange flotation spheres on the mooring George had just given up trying to retrieve. Our cable had severed the mooring. But had the break occurred above or below the all-important current meters?

As I crawl into my top bunk this morning, I'm hoping—as Tupper must have been hoping—that at least one of the meters was still attached. The ship's horn blares a thunderous blast. I know George had gotten that bastard. □

perimental site, says Hollister, who has been investigating trouble with telephone cables for two decades. He suggests that this "may not be a coincidence." However, Ewald will say only that AT&T is interested in evaluating HEBBLE results "as they might affect our cables in the North Atlantic."

Lessons about sediment dynamics—the movement of mud—may also be applied to problems in coastal waters. "It's surprising that we know more about sediment dynamics in the deep sea than in the shallower waters of the continental shelf," Nowell says. "But until HEBBLE, nobody had ever conducted such intense sediment-transport studies anywhere in the ocean." The information could be used to boost the efficiency of dredging operations and improve the structural stability of pipelines, bridge footings, and other structures emplaced on the bottom. "If we could come anywhere near to accurately predicting the sea floor's response to underwater forces such as currents," Hollister says, "we could save millions of dollars in dredging fees and marine construction and repair costs."

The U.S. Navy is interested in benthic storms because of its charge to police and protect home waters, according to Commander Joseph Spigai, former HEBBLE program manager of the Office of Naval Research. "The navy is very interested for a variety of reasons in knowing about the stability of the ocean bottom," he says. "Does it shift around? And if so, how often and where? We think this has some potential applications to our national defense."

Among the navy's ocean-bottom structures and "one of the primary systems that may be affected" by the storms, he says, is the Sound Surveillance System (SOSUS). This is an array of hydrophones used to listen for enemy submarines in the North Atlantic. "Scouring of the bottom may disturb our sensors," Spigai says. "There's a chance that they might be covered and uncovered by the moving sediments."

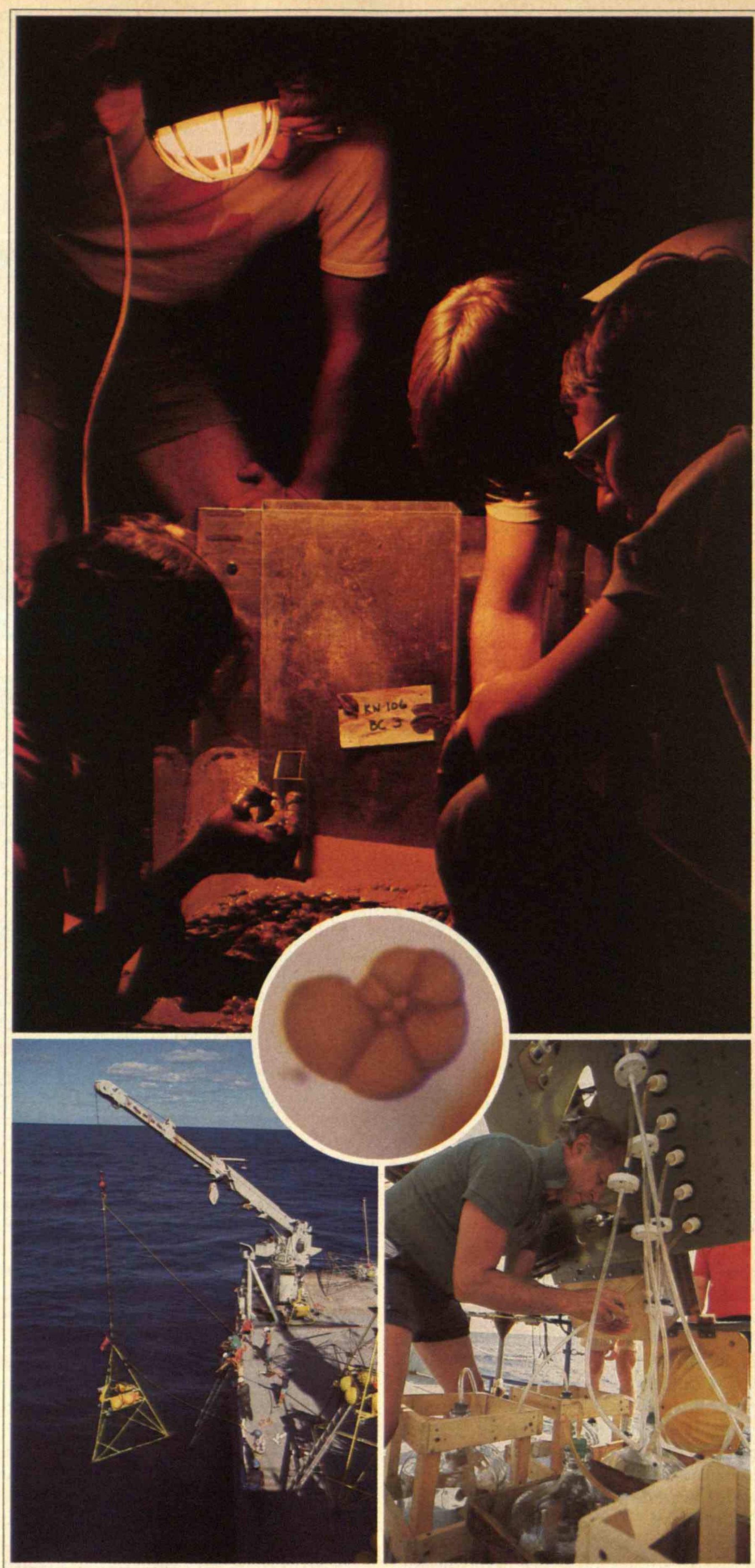
The listening posts may face another

problem as well: HEBBLE investigators theorize that the turbulent storms must be noisy. "As long as the key to locating submarines is listening for the noise they generate, any sound produced by a storm might muffle the acoustic signature of an enemy sub," says Nowell. Spigai agrees that the storms "may mask other noises that the navy might be listening for," adding that "that's about all I can say on the matter."

Benthic storms are also causing geologists to reexamine their ideas about where to search for new reserves of oil. They know that petroleum forms in areas of the sea floor where massive deposits of sediment rich in organic material accumulate quickly, at least by geologic standards. According to the conventional view, the organic-rich sediments—largely the remains of aquatic plants and animals that live near the surface—drift steadily down from above and remain where they hit bottom. But the power of storms to redistribute sediments adds a new wrinkle. Hollister speculates that the areas where ancient storms deposited their sediment loads would have been favorable sites for the formation of oil-bearing rock. Thus, by learning more about how benthic storms work and where they occur, geologists might be able to "look down paleocurrents" to find new oil fields.

The researchers hope to provide clues for petroleum exploration in another way as well. At the HEBBLE site, a certain type of microscopic hard-shelled amoeba—called foraminifera—is more primitive and abundant than similar fauna in apparently storm-free areas. Fossils of these "forams" are also found in oil-bearing rocks in the North Sea and even many places on land. Oil company geologists sometimes use these fossilized forams as markers to help them identify potential reserves. "But forams might become even more useful if we knew more about how they lived in the ancient seas," says Michael Kaminski, a Woods Hole-M.I.T. graduate student. "Therefore, I'm trying to use the present as a key to the past. By studying the forams that live in the mud at the HEBBLE site, we may get a better understanding of the kind of environment that oil-bearing rocks formed in many millions of years ago."

Perhaps the most important question raised by the discovery of benthic storms, however, is their potential effect on hazardous wastes that may be consigned to



Work at sea goes on around the clock. Left: Researchers get a midnight look at mud scooped from the bottom. Inset: This tiny creature thrives in the sediment at the HEBBLE site and may become useful as a "marker" for locating oil reserves. Lower right: Geologist I.N. McCave collects seawater brought up from the depths to analyze its sediment content. Lower left: Another instrument heads for the bottom.

the sea bottom. "When most toxic and radioactive pollutants enter the ocean, they look for fine grains of sediment to call home," says Nowell. "Indeed, sediments scavenge pollutants very effectively—just like Maalox." Thus, storms that move about huge quantities of sediment might move pollutants as well.

For example, the United States and several European nations are studying the feasibility of burying high-level radioactive wastes from nuclear power plants beneath the sea floor. "However, the HEBBLE site and others like it might be damn poor places to put something that you don't want to see again," says HEBBLE biological oceanographer Dave Thistle of Florida State University. One problem is that bacterial activity at the HEBBLE site is unusually high for the deep sea. The storms apparently bring in fresh supplies of oxygen and nutrients, making the area ideal for bacterial growth.

"These bacteria are perfectly willing to mobilize sediments carrying pollutant materials, including metals and radionuclides," says Thistle. "Then the question is whether there is a way for the pollutants to move up the water column." The answer may be yes. He says pollutant-laden bacteria might be eaten by larger bottom-dwelling creatures. Some of the materials excreted by these animals, such as egg cases and fat globules, are buoyant enough to rise to the shallower regions where humankind's food fish live. Thistle stresses, however, that this is still just theory. The HEBBLE researchers have planned more studies of the role bacteria play in mobilizing sediments. If it turns out that bacteria can start pollutants on their way into the food chain, then Thistle says potentially stormy areas probably should be avoided as waste-disposal sites.

But Hollister says there is another way to look at the waste-disposal question. Storms could actually dilute the wastes to safe levels by dispersing them over a broad area. While such a strategy for disposal may ultimately prove to be acceptable, the HEBBLE researchers caution that for now there are more questions than answers. "Before the sea floor is selected as a final dumping ground for any hazardous wastes, we must be able to make reliable predictions about how they will behave over the long-term," says Nowell. "But our mathematical models of sediment dispersion still need verification. They're based at present on numbers that essentially are guesses." The hope, of course, is that HEBBLE will provide the "numbers" needed to improve such predictions.

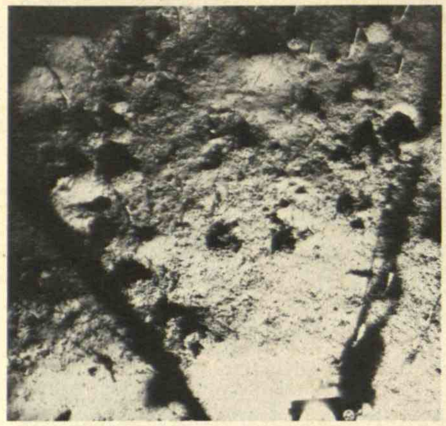
A Radical Notion

The idea that currents in the deep ocean probably move much faster than suspected was proposed early this century by the German physical oceanographer George Wust. But the concept, which he inferred from data on bottom temperature, pressure, and salinity, met with resounding skepticism.

In 1962, Charles Hollister, then a graduate student at Lamont-Doherty Geological Observatory just outside New York City, got his first glimpse at what he thought was a storm-swept seabed while looking at a photograph taken by Lamont geologist Maurice Ewing. Hollister could not accept the conventional reasoning that the ripples and sculpted mounds in the photo had been caused by some earth-shaking geologic event thousands of years ago, possibly during the last ice age. He speculated that something powerful and recent had scoured the seabed and created the ripples.

In 1964, Hollister took his own pictures in the same general area of the North Atlantic that would become the HEBBLE experimental site. The photographs showed more of the same—ripples, mounds, mud waves—and further confirmed his theory. For the most part, however, the scientific community adhered to the traditional notion of a tranquil abyss. Other investigators periodically reported data that indirectly suggested the presence of swift currents in the deep sea. But as late as 1978, there still wasn't enough evidence "to shake a stick at," says Tom Pyle, HEBBLE's first navy program manager and now chief scientist of the National Ocean Service. So when Hollister proposed HEBBLE, "it was a real gamble," says Pyle.

If HEBBLE was indeed a gamble, it started paying off almost immediately. In the summer of 1979, scientists on the first research cruise found deep-sea currents faster than anything even they had imagined. The researchers filtered hundreds of liters of seawater for suspended sediment. Cloudy or muddy samples would indicate the presence of currents powerful enough to lift the fine sediment from the bottom. A reading of 100 to 500 micrograms of sediment per liter would have sufficed to show turbulence; their samples yielded up



In quiet regions of the deep sea, sediments are worked over by bottom-dwelling creatures (left). But benthic storms carry huge quantities of sediment and sweep the bottom smooth (right).

to 12,000 micrograms. "It was astounding," recalls Lamont's Wilf Gardner.

Part of the challenge for HEBBLE researchers has been to develop instruments that can operate in the deep ocean—an environment, says Hollister, that is more hostile than the moon. "There's no rust on the moon because there's no oxygen," he explains. "There's no saltwater to short-circuit your electronics. Saltwater eats metal. In the ocean, animals tend to eat everything they can find. You put a piece of wood or metal down there on the bottom and it becomes a condominium; everybody wants to move in."

The project required sensors that could withstand 7,000 pounds per square inch of pressure and near freezing temperatures while taking measurements continuously for hours or days. The instruments had to be stable enough to endure the jostlings and vibrations from the ship and the bottom blizzards, yet delicate and sophisticated enough to detect the intricate fluctuations of turbulent water and tiny particles of suspended sediment. "It was a tall order," recalls I.N. McCave of the University of East Anglia in Norwich, England.

If an instrument was available but unable to function in the deep ocean, the HEBBLE engineers adapted it for abyssal depths. If a needed instrument didn't exist, they designed and built it. One invention born of necessity, for example, is the Benthic Acoustic Stress Sensor (BASS). Conventional meters used to measure ocean currents rely on mechanical rotors, which can interfere with the flow of water and throw off results. BASS uses sound waves to measure currents. It also does what no other instrument can do—measures water speed and direction twice a second. These instantaneous measurements allow scientists to calculate precisely the stresses that a storm exerts on the bottom when it lifts the sediment.

The instruments are affixed to large steel and fiberglass tripods that free-fall to the abyss. A storm triggers a microprocessor on one of the tripods—called Master BASS—which then acoustically alerts the other sensors to switch themselves on. After a storm, Master BASS orders the sensors to turn off in the same way. Without such "intelligent" remote control and selective sampling, the instruments' recording devices would reach capacity in a matter of hours and their batteries would be quickly used up. Acoustic commands also summon the tripods back to the surface. Flotation spheres—large glass balls encased in brightly colored plastic—give the tripods the buoyancy they need for their long upward journey.

The R/V *Knorr* is scheduled to head out to the HEBBLE site again this summer, marking a new phase in the project, says Hollister. Studies so far have relied on cameras and various instruments to monitor conditions at the sea floor. But this summer's cruise will feature the debut of SeaDuct—a 4,000-pound "laboratory" of pink fiberglass and glistening aluminum that will be lowered to the seabed.

SeaDuct will allow investigators for the first time to create controlled currents on the bottom and measure how the sediments respond. These tests, says Hollister, will provide vital information about the behavior and effects of benthic storms. Indeed, SeaDuct, along with the other HEBBLE studies, will enhance our very meager understanding of the vast, sunless underworld that is perhaps the least known and least studied region of our planet. □

Continued from page 6

Adopted by the U.N. General Assembly in 1979, this "moon treaty" has been ratified by only five nations—Austria, Chile, the Netherlands, the Philippines, and Uruguay. Six more—France, Guatemala, India, Morocco, Peru, and Rumania—have signed it but have not, to date, deposited ratifications. Significantly, neither the United States nor the Soviet Union has signed, although both helped draft the treaty.

There is considerable well-founded concern within the U.S. space community that the moon treaty would put a hammerlock on progress. It would invest control over space development in a U.N. agency that would tax profits and have the right to share the technology involved, largely for the benefit of developing countries. Although this could indeed stifle lunar development, pressure is building within the United Nations to try to adopt such a regime.

Thus, the stage is set for a diplomatic tussle rivaling that involved in drafting the Law of the Sea Treaty. More is at stake than dreams of moon mining; the reach of the treaty might even chill manufacturing projects in Earth orbit.

Whatever the eventual outcome, it is already clear that NASA's vision of an expanding space frontier is credible enough for the rest of the world to want to share in it. Both the United States and the Soviet Union have often piously proclaimed that they were acting on behalf of people everywhere in exploring space. Now both countries must take their rhetoric seriously. As projects unfold that enable us to inhabit low-Earth orbits and set up bases on the moon, the rights and obligations of all nations must be clearly defined—in ways that will not hamper prudent development. This means that NASA and other government agencies must give the highest priority to the evolution of international space law, not just to cooperation with selected nations on specific projects. The space agency should do this by increasing its own legal expertise and working closely on international law with the Departments of Justice and State.

Apollo astronauts left a plaque on the moon proclaiming that "we came in peace for all mankind." When U.S. astronauts return to the moon, probably early in the next century, they may well have to ask the permission of the rest of the world to make such a statement. □

PROFESSIONAL

Quick Flash

The shortest flash of light ever produced is just 16 femtoseconds long—a femtosecond being one millionth of a billionth of a second.

That world record is the work of Professor Erich P. Ippen and two graduate students, James G. Fujimoto and Andrew M. Weiner, who are all in the Optics Communications Group of the Research Laboratory of Electronics.

Why bother?

Because extremely short flashes of light are the key to extremely fast optical computers—faster than possible with conventional electronic signal processing. Minute pulses of light may also lead to a deeper understanding of how electronic materials operate by making possible extremely high-speed imaging, says Ippen. He and his students used laser light compressed by colliding two pulses together to accomplish their new record. □

Managing the Second Industrial Revolution

A new $5 million, five-year study of how information technology will affect management—designed to include a set of guidelines for the transition from today's management to tomorrow's—is beginning in the Sloan School of Management.

New information already gives managers unprecedented ability to store, retrieve, distill, and communicate the information they need to make sound business decisions. There are word processors, electronic mail, databases, video conferences, and many decision-support systems.

Sloan's Professor Lester C. Thurow complains, though, that the result has been more an outpouring of data than an increase in managerial efficiency. Double-entry bookkeeping retains its hold on corporate America even though computers offer quicker, better ways of preventing embezzlement. Executives continue to dictate letters to secretaries who use word processors—devices that make letter writing so quick that the bosses themselves should be using them. "A boss without the ability to type at more than 60 words per minute is obsolete," Thurow wrote recently in the *Boston Globe*.

Professor Michael Scott Morton of the Sloan School says that today's changes, and the problems and opportunities they create, are only the tip of an iceberg. Scott Morton and his colleagues see information technology as the driving force behind what they call a second industrial revolution, with profound effects on the structure, processes, and roles in major corporations. Scott Morton speaks of "whole new ways to manage the firm . . . new markets, products, and services."

High Tech and the Multiplier Effect

Considered as an isolated sector, high technology has a modest—almost miniscule—effect on the U.S. economy. High-technology companies are typically small, their products tend to displace workers instead of creating new jobs, and their needs for capital are modest.

But high technology is indispensable because of the multiplier effect on other sectors in the U.S. economy.

After a two-year study for the Small Business Foundation of America and other sponsors, Professor David L. Birch and his associate Susan J. McCracken make a sharp distinction between high-technology, high-innovation, and high-growth sectors of the economy. High-technology firms are innovators and likely to be fast-growing. High innovators—airlines, petroleum refiners, and health industries, for example—have a special talent for capitalizing on high technology, and they are the source of new products and services that large corporations need for success. The latter have a commanding effect on the economy because of their sheer size. Furthermore, today's high innovators are likely to be tomorrow's major corporations.

"There is no need to produce technology to reap its benefits," says Birch. □

Free Market, Low Price for Natural Gas

Users of natural gas are on a knife-edge of uncertainty: will there be enough gas, and how much will it cost?

The answers: a shortage, if there is one, will be artificial. And whatever the price, it may or may not bear any relationship to real supply and demand.

Two policy changes would greatly improve the operation of the natural-gas market, say Paul R. Carpenter and Arthur W.

Wright of the M.I.T. Energy Laboratory:

☐ Decontrol all gas prices. (As it stands, prices of gas from deposits discovered since 1977 were decontrolled on January 1, 1985, but "old" gas will continue under ceilings established in 1978.

☐ Free pipeline companies to sell gas to distributors to whom they are not now committed.

Carpenter and Wright insist that decontrol of "old" as well as "new" gas would not necessarily cause the price to go up. The price of "old" gas would, of course, rise when decontrolled, and production from these "old" wells would accordingly increase. But that new production of medium-priced "old" gas could well replace expensive "new" gas in the system, with the result that the average price to most consumers would fall.

As it stands, pipeline companies must reserve most of their capacity to fulfill standing obligations—a constraint that sharply restricts competition in the natural-gas business.

In a time of surplus—there is now more gas available than the nation needs, despite grim the warnings of a decade ago—these two measures would work together to make gas prices far more responsive to supply and demand than they are now. Carpenter and Wright even foresee a national spot market, which they call "the ultimate mechanism of market flexibility," in natural gas. ☐

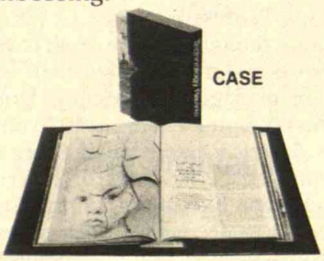
When Computers Fail

The computer may be watching over you, but the results may not be so very useful in law enforcement after all.

Consider, for example, the well-publicized computer matching of welfare checks and Massachusetts bank-statement records to detect welfare fraud. It sounds simple, but it is simplistic, say Professor Gary T. Marx and Nancy Reichman of M.I.T. The sophisticated criminal will simply convert assets to a form the computer cannot find—such as out-of-state bank accounts.

Furthermore, such computer-based detection systems, say Marx and Reichman, raise important civil-liberties issues, tending to "transform the presumption of innocence into an assumption of guilt."

Marx is professor of sociology in the Department of Urban Studies and Planning, and Reichman recently received her Ph.D. degree from the department. ☐



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